NEUROPSYCHOLOGICAL FUNCTIONING OF OEF/OIF COMBAT VETERANS
WITH POSTTRAUMATIC STRESS DISORDER

BY

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DISSERTATION

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Abstract

The purpose of the present study was to investigate the neuropsychological functioning of Operation Enduring Freedom (OEF) and Operation Iraqi Freedom (OIF) combat veterans with Posttraumatic Stress Disorder (PTSD). More specifically, this study sought to examine whether the neuropsychological functioning of OEF/OIF combat veterans with PTSD and a comorbid mild traumatic brain injury (TBI) significantly differed from those with uncomplicated PTSD across multiple tests of cognitive functioning. To accomplish this objective, the medical records and neuropsychological assessment data of 59 OEF/OIF combat veterans with PTSD and 66 OEF/OIF combat veterans with PTSD and comorbid mild TBI were examined and included for statistical analysis. Results of this study yielded three main conclusions. First, neither group of OEF/OIF combat veterans demonstrated notable performance deficits across the battery of cognitive tests examined in this study. Second the neuropsychological functioning of OEF/OIF combat veterans with PTSD and mild TBI did not differ significantly from those combat veterans with uncomplicated PTSD across the measures of cognitive functioning examined. Finally, both groups reported depressive and anxiety symptoms in the moderate severity range, which suggests that both groups experience elevated levels of comorbid psychopathology.

To the memory of my grandmother, Katherine Sobolewski; I wish you could have been here to see me complete what you saw me begin

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Chapter 1

Introduction

Numerous symptoms of Posttraumatic Stress Disorder (PTSD) have been observed in association with combat exposure dating as far back as the United States Civil War (Hyams, Wignall, & Roswell, 1996; Monson, Friedman, & La Bush, 2007; Oltmanns, Neale, & Davison, 2003). Since its introduction into diagnostic nosology (i.e., *Diagnostic and Statistical Manual of Mental Disorders [DSM-III];* American Psychiatric Association [APA], 1980), mental health professionals' understanding of this disorder, its prevalence, and related sequelae have evolved considerably (Resick, Monson, & Rizvi, 2008b). While lifetime PTSD prevalence rates of approximately 7-8% have been found in the general population, notably higher PTSD rates have been documented in "at-risk" groups such as combat veterans (APA, 2000; Resick et al., 2008b Vasterling, 2005). In the current wars in Afghanistan and Iraq, for example, PTSD rates as high as 20-22% have been reported (Hoge et al., 2004; Seal et al., 2009). Although the psychological consequences associated with PTSD are multifaceted, neuropsychological functioning is one specific area that is negatively affected by PTSD which may result in impaired coping resources as well as psychosocial, educational, and occupational functioning (Gil, Calev, Greenberg, Kugelmass, & Lerer, 1990; McNally & Shin, 1995; Vasterling & Brailey, 2005). Because PTSD is complicated in the current wars by prevalent comorbid mild traumatic brain injury (TBI), the purpose of the current study is to examine the neuropsychological effects of PTSD, with special emphasis on those combat veterans presenting with PTSD and comorbid mild TBI.

New Wars, Different Battle Injuries

The current wars in Afghanistan (Operation Enduring Freedom [OEF]) and Iraq (Operation Iraqi Freedom [OIF]) are somewhat unique operations in United States military history (Fontana & Rosenheck, 2008; Grieger & Benedek, 2006). Perhaps the most salient difference between Afghanistan and Iraq and previous wars is the battle-related injuries sustained by combat troops (Darkins, Cruise, Armstrong, Peters, & Finn, 2008; Sayer et al., 2008). Unlike previous conflicts where attacks typically involved firearms or grenades, powerful blast weapons such as improvised explosive devices (IEDs), mortar shells, rocket-propelled grenades, landmines, as well as car and suicide bombings constitute the more common weapons and attack tactics used by enemy combatants (Grieger & Benedek, 2006; Sayer et al., 2008). While more advanced equipment such as Kevlar body armor and increased medical technology and response time have resulted in decreased fatalities relative to previous wars, blast exposure often still results in bodily injury, particularly to areas of the body not fully protected by armor such as the extremities, head, and neck (Belanger, Kretzmer, Yoash-Gantz, Pickett, & Tupler, 2009; Okie, 2005; Sollinger, Fisher, & Metscher, 2008; Xydakis, Fravell, Nasser, & Casler, 2005). As such, the heavy use of powerful explosive devices has resulted in a high prevalence of blast-related injuries, and most notably, mild TBIs among OEF/OIF combat troops (Belanger et al., 2009; Okie, 2005; 2006). Because of their high prevalence (e.g., 19%; Tanielian & Jaycox, 2008), TBIs often are referred to as the "signature wound" (Okie, 2006, p. 2609) of these wars. Thus, the high rates of mild TBI among combat troops in the wars in Afghanistan and Iraq, present a new challenge for understanding the cognitive dysfunction associated with PTSD for combat veterans.

Because of the increase in blast-related injuries and resulting TBIs, these wars have produced a population of polytrauma combat veterans with PTSD and comorbid TBI in addition to those with classic PTSD. For instance, Hoge and colleagues (2008) found PTSD rates of approximately 44% in OEF/OIF combat troops who sustained a TBI that resulted in loss of consciousness. Likewise, Lew et al. (2007) reported that 42% of OEF/OIF veterans with a mild TBI also displayed symptoms of PTSD at post-deployment screening. These findings raise the question of whether the neuropsychological functioning of combat veterans with PTSD and a comorbid TBI differs from previous cohorts of combat veterans with uncomplicated PTSD. In addition, this comorbidity is further complicated in that PTSD and mild TBI often result in overlapping cognitive symptoms (Tanielian, Jaycox, Schell, Marshall, & Vaiana, 2008). For example, problems with attention, concentration, and memory are common symptoms of both PTSD as well as TBI (Burnam et al., 2008; Helmick et al., 2006; Warden, 2006). To date, many studies examining PTSD and TBI (see Hoge et al., 2008; Lew et al., 2007) have focused on describing the overall prevalence rates among OEF/OIF combat troops and veterans. While some reviews (e.g., Lew et al., 2008) have discussed potential implications for providing treatment services to combat veterans presenting with these comorbid conditions, research investigating the neuropsychological functioning of OEF/OIF combat veterans with PTSD and TBI compared to those with uncomplicated PTSD has been limited. Thus, the present study examined the neuropsychological functioning of OEF/OIF combat veterans with PTSD and comorbid mild TBI to investigate whether their objective test performance significantly differs from OEF/OIF combat veterans with uncomplicated PTSD.

PTSD and TBI: Previous Findings

Post-traumatic stress disorder. Previous research has examined the course and cognitive impairment associated with PTSD and mild TBI as separate conditions. Findings generally support the position that individuals with PTSD demonstrate impaired performance on objective testing across certain domains of neuropsychological functioning (see Horner & Hamner, 2002 for a review). For example, attention is one domain of functioning where individuals with PTSD perform consistently worse than individuals without PTSD (Gilbertson, Gurvits, Lasko, Orr, & Pitman, 2001; Horner & Hamner, 2002). The *DSM-IV-TR* (APA, 2000) acknowledges this overlap in the diagnostic criteria for PTSD (i.e., difficulty concentrating) (Vasterling & Brailey, 2005). Additionally, neuropsychological impairment associated with PTSD has been found with learning and memory (Gilbertson et al., 2001; Sachinvala et al., 2000; Uddo, Vasterling, Brailey, & Sutker, 1993; Vasterling, Brailey, Constans, & Sutker, 1998); executive functioning (Gilbertson et al., 2001; Koso & Hansen, 2005); language fluency (Uddo et al., 1993; Yehuda et al., 1995); visuospatial functioning (Gilbertson et al., 2001; Gurvits et al., 2002); and premorbid intellectual functioning (Gilbertson et al., 2001; Gurvits et al., 2002; Vasterling et al., 1998), although lower premorbid intelligence likely is a risk factor for developing PTSD rather than a result of the disorder (Vasterling et al., 2002). Finally, PTSD often is a chronic condition that can persist for years among combat veterans, as evidenced by multiple studies that found performance deficits among Vietnam veterans decades after the Vietnam War ended (e.g., Gilbertson et al., 2001; Gurvits et al., 1993; Uddo et al., 1993; Vasterling et al., 2002).

Traumatic brain injury. Many common symptoms of mild TBI such as broad problems with attention, concentration, and memory are similar to cognitive difficulties observed with PTSD (Burnam et al., 2008; Helmick et al., 2006; Warden, 2006). However, unlike PTSD, cognitive symptoms associated with mild TBI frequently decrease over time on a fairly consistent basis with approximately 80-90% of individuals with a mild TBI recovering from the associated cognitive impairments within one year, many within 30 days (Frencham, Fox, & Maybery, 2005; Lucas & Addeo, 2008; Michigan Department of Community Health, 2009; Ruff, 2005).

The difference in the typical course and outcome for PTSD and TBI as separate conditions raises the issue of how the neuropsychological functioning of OEF/OIF combat veterans with both conditions (i.e., PTSD and a comorbid mild TBI) is impaired after the typical recovery period for mild TBI. More specifically, it seems that two possible outcomes exist. One possibility is that each condition will follow its typical course. That is, combat veterans with both conditions will recover from the TBI and that any residual neuropsychological impairment observed on objective testing will not differ significantly from combat veterans with uncomplicated PTSD. Alternatively, PTSD and comorbid mild TBI may result in a compounding effect that produces either (a) impairment across more domains of cognitive functioning or (b) more severe impairment in domains previously found to be affected by PTSD. Preliminary findings (e.g., Belanger, Kretzmer, Vanderploeg, & French, 2010; Hoge et al., 2008) suggest that self-reported mild TBI symptoms may not remain significant after PTSD symptom severity is taken into account. This study sought to investigate this issue further by examining the cognitive performance of OEF/ OIF combat veterans with PTSD and comorbid mild TBI across multiple domains of neuropsychological functioning on a comprehensive battery of cognitive tests.

Purpose and Rationale of the Present Study

As increasing numbers of OEF/OIF combat veterans with PTSD and TBI seek treatment within the VA healthcare system, it is imperative to investigate the neuropsychological sequelae of these war injuries. As Lew and colleagues (2008) discussed, many of the current treatments for PTSD were developed with past cohorts of combat veterans who experienced more chronic PTSD and it is unknown whether these same interventions will meet the treatment needs of this new population of combat veterans who present with more acute PTSD or PTSD and TBI. Thus, the purpose of this study was to examine and compare the neuropsychological performance of OEF/OIF combat veterans diagnosed with PTSD to those diagnosed with PTSD and comorbid mild TBI. Specifically, this study investigated the comprehensive neuropsychological test performance of both groups of OEF/OIF combat veterans across the seven central domains of neuropsychological functioning: (1) attention; (2) learning and memory; (3) executive functioning; (4) language; (5) visuospatial functioning; (6) motor functioning; and (7) intellectual functioning.

The present study had four primary objectives. The first was to examine and describe the overall patterns of neuropsychological test performance and to document any performance deficits that were observed across domains of neuropsychological functioning. Moving beyond description, the second objective of this study was to compare patterns of neuropsychological test scores between the two groups in order to investigate whether significant differences in functioning exist. Because limitations may arise when attempting to make meaningful inferences based on single neuropsychological test scores (Hannay & Lezak, 2004), neuropsychological profiles were used to investigate overall patterns of functioning and impairment. For over a half-century psychologists (see Meehl, 1950) have discussed the clinical utility of examining patterns or profiles of psychological test scores to detect differences that may not necessarily be evident by examining individual test scores. As such, both between-domains neuropsychological profiles that examined patterns of performance across the domains of neuropsychological functioning, as well as within-domain profiles that examined the more nuanced components of individual domains were constructed and analyzed to determine if significant differences existed between groups. The third objective of this study was to investigate whether test performance in any of the seven domains of neuropsychological functioning could predict PTSD versus PTSD and mild TBI diagnostic group membership. Finally, this study sought to investigate the psychological functioning of both groups of OEF/OIF combat veterans in order to determine if either group experienced significantly different levels of comorbid psychopathology. The specific research questions guiding this study were as follows:

1. Which domain(s) of neuropsychological functioning are impaired among OEF/OIF combat veterans with PTSD versus those with PTSD and mild TBI?
2. How does OEF/OIF neuropsychological test performance compare with findings from previous cohorts of combat veterans?
3. Do the between-domains neuropsychological profiles of OEF/OIF combat veterans with PTSD differ from combat veterans with PTSD and mild TBI across the seven central domains of functioning? If so, how do they differ?
4. Do the within-domain neuropsychological profiles of OEF/OIF combat veterans with PTSD differ from combat veterans with PTSD and mild TBI in any domain(s)? If so, how do they differ?
5. Does test performance in any of the seven central domains of neuropsychological functioning predict PTSD versus PTSD and comorbid mild TBI diagnostic group membership?
6. Does self-reported psychological functioning differ between OEF/OIF combat veterans with PTSD compared to those with PTSD and mild TBI?

Chapter 2

Review of the Literature

This review of the literature begins with a thorough description of the history, diagnostic criteria, course, and prevalence of Posttraumatic Stress Disorder (PTSD) with special emphasis on the high rates of this disorder found among combat troops and veterans. Next, I detail previous empirical findings documenting the impact of PTSD across the seven central domains of neuropsychological functioning in previous cohorts of US combat veterans. I then outline the unique nature of the current conflicts in Afghanistan and Iraq as well as the hallmark combat injuries distinct to Operation Enduring Freedom (OEF) and Operation Iraqi Freedom (OIF) combat veterans, most notably mild Traumatic Brain Injuries (TBIs). Furthermore, I discuss emerging research documenting the increased prevalence of comorbid PTSD and mild TBI among OEF/OIF combat veterans. In particular, I describe the symptom overlap between PTSD and mild TBI and explain potential differences in overall neuropsychological functioning between combat veterans with uncomplicated PTSD and those with comorbid PTSD and TBI. Finally, I describe the present study, which is designed to investigate the neuropsychological functioning of OEF/OIF combat veterans with PTSD including those who suffer from PTSD and mild TBI on objective testing.

An Overview of Posttraumatic Stress Disorder

According to the *Diagnostic and Statistical Manual of Mental Disorders*, 4th edition, *Text Revision* (*DSM-IV-TR*; APA, 2000), PTSD is classified as an anxiety disorder. It is characterized by a group of distressing symptoms that develop following exposure to a traumatic stressor in which an individual “experienced, witnessed, or was confronted with an event or events that involved actual or threatened death or serious injury, or a threat to the physical integrity of self or others" (p. 476). Examples of traumatic stressors that can result in PTSD include experiencing sexual assault, natural disasters, accidents, and military combat (Ehlers & Clark, 2006). As Resick, Monson, and Rizvi (2008b) noted, PTSD represents a somewhat unique entry in current diagnostic nosology in that an identifiable external event (i.e., traumatic stressor) must have occurred prior to the onset of the disorder. Specifically, *DSM-IV-TR* PTSD Criterion A requires that a person experienced a traumatic event that endangered his or her life or physical well-being and elicited a strong, negative emotional reaction such as "fear, helplessness, or horror" (APA, 2000, p. 476).

In addition to experiencing a traumatic event, PTSD criteria also include reexperiencing symptoms (Criterion B), avoidance symptoms (Criterion C), and increased arousal symptoms (Criterion D). These symptoms must be present for at least one month and cause significant distress and impairment across multiple domains of an individual's life. At least one of the five reexperiencing symptoms (Criterion B) is required for a PTSD diagnosis. They include: (1) recurrent and intrusive recollections of the event; (2) recurrent distressing dreams of the event; (3) acting or feeling as if the event were recurring (e.g., flashbacks); (4) intense psychological distress to cues that resemble the event; and (5) physiological reactivity to cues that resemble the event. The seven avoidance symptoms (Criterion C), of which at least three are required, include: (1) efforts to avoid thoughts, feelings, or conversations associated with the trauma; (2) efforts to avoid activities, people, or places that are associated with the trauma; (3) an inability to recall important aspects or the trauma; (4) diminished interest or participation in activities; (5) feelings of detachment or estrangement; (6) restricted range of affect; and (7) a sense of a foreshortened future. The five symptoms of increased arousal include (1) difficulty falling or staying asleep; (2) irritability or outbursts of anger; (3) difficulty concentrating; (4)

hypervigilance; and (5) exaggerated startle response. At least two of these five increased arousal symptoms must be present to qualify for a diagnosis of PTSD. Finally, *DSM-IV-TR* (APA, 2000) classifies PTSD as chronic if symptoms persist for more than three months.

Historical Development of PTSD

Although the specific diagnostic entry of PTSD did not exist prior to *DSM-III* (APA, 1980), many of the hallmark symptoms of PTSD as they are understood today had been recognized among combat soldiers dating as far back as the United States Civil War. These symptoms were referred to by various labels over the past one and a half centuries including "Nostalgia" after the Civil War, "Shell Shock" and "Trench Neurosis" after World War I, and "Battle Fatigue" and "Combat Exhaustion" after World War II and The Korean War (Hyams et al., 1996; Monson et al., 2007; Oltmanns et al., 2003). Following World War II, the broad symptoms of what is now classified as PTSD were categorized as a "Gross Stress Reaction" under Transient Situational Personality Disorders in the first edition of the *DSM* (*DSM-I*; APA, 1952). However, this diagnostic entry was omitted in the subsequent edition of the manual (Oltmanns et al., 2003). Specifically, *DSM-II* (APA, 1968) combined the "Gross Stress Reaction" entry with "Adult Situation Reaction" into a single diagnostic entry of "Adjustment Reaction of Adult Life." The current diagnostic category of PTSD was incorporated into the *DSM* classification system in the *DSM-III* (APA, 1980) partially in response to the aftermath of the Vietnam War and the women's movement, both of which highlighted the psychological effects of trauma exposure (Resick et al., 2008b).

Prevalence of PTSD

A review of epidemiological research indicates that exposure to traumatic stressors is somewhat common among the general population. For example, according to the National

Comorbidity Survey, approximately 61% of men and 51% of women indicated that they have experienced at least one traumatic event in their life (Kessler, Sonnega, Bromet, Hughes, & Nelson, 1995). Similarly, Resnick, Kilpatrick, Dansky, Saunders, and Best (1993) found that in a random sample of 4,008 U.S. women, 69% had reported that they experienced at least one traumatic event in their lifetime. Vrana and Lauterbach (1994) also reported trauma exposure rates of 84% for experiencing at least one lifetime traumatic event and at 33% for experiencing four or more traumatic events in a nonclinical sample of college undergraduates. Collectively, these results suggest that the overall prevalence of trauma exposure is quite high. Despite the relatively high rates of trauma exposure in the general population, most individuals who experience a traumatic event experience a natural recovery process for any initial symptoms and do not progress to develop PTSD (Foa, Hembree, & Rothbaum, 2007; Hembree & Feeny, 2006; Keane, Weathers, & Foa, 2000; McNally, 2003).

A sizeable fraction of trauma survivors do not experience this natural recovery process and continue to suffer from chronic PTSD symptoms that do not abate over time (Foa et al., 2007). Lifetime PTSD prevalence rates of approximately 6.8-8% have been found in the general adult population (APA, 2000; Kessler et al., 1995; Kessler et al., 2005). These PTSD prevalence rates suggest that while the chances of actually developing PTSD are significantly lower relative to the probability of experiencing a traumatic event, a significant portion of the population who were exposed to trauma will develop symptoms consistent with PTSD. Furthermore, it also has been found that PTSD rates are much higher for populations that are considered at-risk such as combat veterans and survivors of terrorists' attacks and natural disasters (Duke & Vasterling, 2005; Resick et al., 2008b).

While several at-risk populations exist, this review primarily focuses on combat veterans. In 1983, the U.S. Congress mandated that the Department of Veterans' Affairs assemble a team of researchers to conduct a large-scale, independent study to assess PTSD as well as other psychosocial and adjustment difficulties, among Vietnam combat veterans (Schlenger et al., 2005). This study, the National Vietnam Veterans Readjustment Study (Kulka et al., 1990), represented the largest study of combat veterans to date and involved objective psychological assessment and in-depth structured clinical interviews among Vietnam theatre veterans, non-combat veterans, and non-veterans (total n = 3,016). Results indicated that 31% of male veterans and 27% of female veterans met criteria for PTSD at some time after the war. Further, at the time of the study, over ten years after the war ended, 15% of male veterans and 9% of female veterans still met criteria for PTSD. In response to criticism that PTSD rates were inflated, Dohrenwend and colleagues (2006) applied more stringent criteria to these data and included only traumatic events that were verified by official records. They found that 18.7% of veterans met criteria for war-related PTSD at some point in their lives, while 9.1% still met diagnostic criteria for PTSD. These stringent estimates should be considered the minimum rates of PTSD because some Vietnam combat veterans may have been exposed to traumatic events not reflected in official records (Resick, Monson, & Rizvi, 2008a).

The current wars in Afghanistan and Iraq present a novel opportunity for scientific investigation of PTSD because they have allowed for active assessment of PTSD during wartime as opposed to retrospective investigation used in post-Vietnam War studies (Hoge, Auchterlonie, & Milliken, 2006; Hoge et al., 2004; Litz & Schlenger, 2009). Specifically, researchers reported rates of PTSD as high as 20-22% among combat OEF/OIF combat veterans (Hoge et al., 2004; Seal et al., 2009). In addition, PTSD was associated with numerous physical and psychosocial difficulties including more frequent and severe somatic and physical complaints, poorer self-rated health, and more missed workdays (Eibner, Ringel, Kilmer, Pacula, & Diaz, 2008; Hoge et al., 2007). While PTSD is complex and multifaceted, a comprehensive discussion of all areas of functioning affected by this disorder is beyond the scope of this review. Instead, the next section of this review examines the effects of PTSD on combat veterans' neuropsychological functioning. Neuropsychological impairments associated with PTSD often are observed across multiple domains of cognitive functioning and these difficulties can detrimentally affect many areas of daily functioning, including the ability and mental resources to cope with PTSD (Brewin, 2005; Vasterling & Brailey, 2005).

The Neuropsychology of PTSD: Previous Findings

Since PTSD was incorporated into *DSM* nosology, scholars have begun to investigate its impact on individuals' overall cognitive and neuropsychological functioning (Horner & Hamner, 2002; Uddo, Vasterling, Brailey, & Sutker, 1993). Difficulties across multiple cognitive domains such as poor memory, trouble concentrating, and difficulty paying attention are commonly reported among individuals diagnosed with PTSD (Uddo et al., 1993; Vasterling, 2007; Wolfe & Charney, 1991). As Vasterling and Brailey (2005) indicated, neuropsychological impairments, specifically those observed in the broad domains of attention and memory, constitute core features of this disorder. For example, two of the *DSM-IV-TR* (APA, 2000) diagnostic criteria for PTSD reflect cognitive impairment: (1) inability to recall an important aspect of the trauma (Criterion C3) and (2) difficulty concentrating (Criterion D3). Interestingly, some studies found no association between PTSD and individuals' neuropsychological functioning on objective testing (e.g., Barrett, Green, Morris, Giles, & Croft, 1996; Crowell, Kieffer, Siders, & Vanderploeg, 2002; Zalewski, Thompson, & Gottesman, 1994), though the results of these studies should be interpreted cautiously as the participants and measures were all drawn from the same database. Thus, the findings likely are not independent (Duke & Vasterling, 2005; Vasterling & Brailey, 2005). Although some studies failed to detect significant associations, empirical research generally supports this association between PTSD and objective neuropsychological performance deficits across certain domains of cognitive functioning (e.g., Horner & Hammer, 2002; Vasterling & Brailey, 2005). Therefore, in this section I review and summarize previous empirical literature on the effects of PTSD across seven central domains of neuropsychological functioning: (1) attention; (2) learning and memory; (3) executive functioning; (4) language; (5) visuospatial functioning; (6) motor functioning; and (7) intellectual functioning.

Attention

Attention has been defined as "the directivity and selectivity of mental processes" (Luria, 1973, p. 256) and encompasses a set of cognitive functions related to filtering, focusing, tracking, and mentally manipulating information (Hebben & Milberg, 2002; Strauss, Sherman, & Spreen, 2006). Impaired attention is perhaps one of the most frequent subjectively reported and objectively observed neuropsychological impairments of PTSD and is represented among the *DSM-IV-TR* diagnostic criteria (APA, 2000; Vasterling & Brailey, 2005).

Attention often is conceptualized as a multidimensional construct, and it has been suggested that various components may be affected differently by PTSD (Cohen, Malloy, Jenkins, & Paul, 2008; Vasterling & Kleiner, 2005). For instance, Mirsky, Anthony, Duncan, Ahearn, and Kellam (1991) proposed a four-factor model of attention that included the following elements: (1) focus-execute (i.e., the ability to select target information from the environment and respond to them); (2) shift (i.e., the ability to change the focus of attention); (3) sustain (i.e., the ability to maintain focus and vigilance over time); and (4) encode (i.e., the ability to sequentially register, recall, and manipulate information). Using this four-factor model, Vasterling, Brailey, Constans, and Sutker (1998) found that Gulf War veterans with PTSD performed significantly worse on measures related to the sustain and encode elements of attention. Vasterling and colleagues (2002) also found similar neuropsychological deficits in the sustain and encode but not in the focus-execute or shift elements of attention among a sample of Vietnam combat veterans with PTSD. These results suggest that PTSD may affect some dimensions of attention more severely than others.

Although conceptual models of attention have been proposed in which attention is composed of multiple, discrete components, in actual clinical practice the components of attention often are interrelated. Few cognitive tests measure one single component in isolation (Hebben & Milberg, 2002; Lezak, Howieson, & Loring, 2004; Strauss et al., 2006), and researchers also have examined attentional abilities more globally without a specific conceptual model. For example, Uddo et al. (1993) found that Vietnam combat veterans with PTSD performed significantly worse on several measures of visual attention and tracking abilities compared to a group of Army National Guard enlistees with no history of exposure to traumatic stressors. Likewise, Sachinvala et al. (2000) found that Vietnam combat veterans with PTSD performed significantly worse than a matched control group on multiple tests of attention on the Cognitive Evaluation Protocol, a patient self-administered, computerized assessment of cognitive functioning and mood (McGuire et al., 2000). Lindem and colleagues (2003) also found a significant association between PTSD and sustained attention, with greater symptom severity being correlated with lower performance scores among Gulf War veterans. Finally, Gilbertson, Gurvits, Lasko, Orr, and Pitman (2001) found that attention performance emerged as an independent predictor that discriminated between Vietnam combat veterans with PTSD from those without PTSD. Collectively, these findings offer further support that PTSD is associated with broad attentional performance deficits among combat veterans as well.

Before discussing empirical findings across the other domains of cognitive functioning, it is critical to note that attention has been referred to as “the building block on which other cognitive abilities rely” (Hebben & Milberg, 2002, p. 104). Thus, attention constitutes a core component of cognitive functioning that interacts with other domains of neuropsychological functioning such as memory and executive functioning. Impaired attention likely will affect other domains of neuropsychological functioning (Amici & Boxer, 2007; Cohen et al., 2008; Hebben & Milberg, 2002; Vasterling & Brailey, 2005).

Learning and Memory

Lezak et al. (2004) conceptualized memory as a set of interacting components and cognitive processes that require the intact functioning of multiple systems. Thorough evaluation entails “assessing encoding and acquisition of information, retention and retrieval, rate of decay, and susceptibility to interference, as well as recognition memory versus spontaneous recall” (Hebben & Milberg, 2002, p. 109). Broadly speaking, the empirical literature has linked PTSD to memory dysfunction. For example, Gilbertson and colleagues (2001) found that Vietnam combat veterans performed significantly lower on the General Memory Index of the *Wechsler Memory Scale-Revised* (*WMS-R*; Wechsler, 1987) than combat veterans without PTSD. Similar to attention, this General Memory Index also independently discriminated between combat veterans with PTSD from those without the disorder. Furthermore, empirical findings also provide evidence that PTSD impairs several types and components of learning and memory performance on objective neuropsychological testing (Horner & Hamner, 2002; Vasterling, 2007; Vasterling & Brailey, 2005). Below, I discuss three such types: short-term memory, verbal learning and memory, and visual memory.

Multiple studies have indicated that PTSD impairs short-term (or immediate) memory functioning (see Horner & Hamner, 2002 for a review). For instance, in an early pilot study, Everly and Horton (1989) reported that individuals with PTSD demonstrated impaired short-term memory performance. Bremner and colleagues (1993) also found that Vietnam combat veterans with PTSD performed significantly worse than those without the disorder across multiple measures of memory and concluded that PTSD may result in impairments short-term memory. Similarly, Sachinvala et al. (2000), found that combat veterans with PTSD performed significantly worse than those without PTSD on both short-term and extended memory tasks.

Several aspects of verbal learning and memory also were found to be affected by PTSD. For example, Uddo et al. (1993) found that relative to a group of enlistees without PTSD, Vietnam combat veterans with PTSD displayed poorer acquisition of words across five trials of a word list learning test. Despite differences in learning and immediate recall, no significant differences were detected in delayed recall between the groups. The PTSD group also displayed greater proactive interference (i.e., previously learned information interfering with the recall of newer information). Using a similar design, Yehuda et al. (1995) found that combat veterans with PTSD did not differ from control subjects on learning, acquisition, immediate memory, or proactive interference, but they did identify significantly greater retroactive interference (i.e., more recent information interfering with the recall of previously learned information) among the PTSD combat veterans. Vasterling et al. (1998) reported that memory deficits on neuropsychological testing were not global, but that compared to non-PTSD veterans, Gulf War veterans with PTSD performed poorer in the initial acquisition and learning of new information and demonstrated greater retroactive interference. No significant differences in proactive interference and long term retention were found after controlling for initial learning. Furthermore, on a recognition test, veterans with PTSD had significantly more false positives, but not more correct hits relative to non-PTSD veterans. Similarly, Vasterling et al. (2002) found that Vietnam combat veterans with PTSD also performed poorer in the initial acquisition and learning of new information.

A number of studies have yielded less consistent results regarding the effects of PTSD on visual learning and memory. For instance, Uddo et al. (1993) found that Vietnam combat veterans with PTSD demonstrated significantly worse immediate recall on a complex figure reproduction task compared to veterans without PTSD. Gilbertson and colleagues (2001) reported no significant differences between Vietnam combat veterans with and without PTSD on immediate recall of this same complex figure reproduction task, but found that combat veterans with PTSD performed significantly worse on the Visual Memory Index of the *WMS-R*. Vasterling and colleagues (2002) found no significant differences between Vietnam combat veterans with PTSD and veterans without mental disorders in learning and delayed recognition on a continuous visual memory test. However, Vasterling and colleagues (1998) found significant differences in learning and delayed recognition on this same continuous visual memory test between Gulf War combat veterans with PTSD and psychopathology-free veterans. Interestingly, these observed differences in delayed recognition no longer remained significant once initial learning was entered as a covariate, suggesting that PTSD affects initial acquisition of information. The PTSD group also demonstrated a significantly greater number of false positives on this test as well.

Several common findings emerged from studies examining the effect of PTSD on learning and memory discussed above. First, short-term memory is one type of memory that research has found to be affected by PTSD (Horner & Hamner, 2002). Second, PTSD seems to result in verbal, and to lesser extent, visual learning and memory dysfunction, though distinct components are likely to be observed (Vasterling et al., 1998; 2002). For example, initial acquisition and learning of information is likely to be impaired in combat veterans with PTSD compared to individuals without PTSD. In addition, findings suggest that PTSD is associated with more interference that impairs memory performance on verbal learning tests. Finally, the evidence suggests that performance deficits on tasks that measure delayed recall appear not to remain significant once the impact of prior impaired acquisition and learning is taken into account (Vasterling & Brailey, 2005).

Executive Functioning

Executive functioning encompasses "numerous higher-order cognitive functions of establishing, maintaining and changing set; initiation; planning and organization; judgment; reasoning and abstraction; and self-regulation" (Hebben & Milberg, 2002, p. 107). Though the definition remains somewhat nebulous across clinicians and researchers, executive functioning broadly refers to a broad set of complex cognitive abilities and behaviors related to planning, formulating goals, anticipating consequences, purposeful behavior, self-regulation, modification of behavior, mental flexibility, and responding adaptively to new conditions thought to be influenced by the frontal lobes (Kramer & Quitania, 2007; Lezak et al., 2004; Malloy, Cohen, Jenkins, & Paul, 2008; Stuss, 2007). Because much of the previous research has not specifically examined executive functioning when assessing the cognitive impairment associated with PTSD, the effects of PTSD on this domain of cognitive functioning are not well understood (Horner &

Hamner, 2002). Furthermore, scholars (e.g., Cummings & Miller, 2007; Vasterling & Brailey, 2005) have noted that executive functioning does not operate independently from other domains of neuropsychological functioning, such as attention, memory, or language, which also complicates defining and measuring this domain.

Although findings have been limited relative to other domains of neuropsychological functioning, results from studies that specifically examined executive functioning generally suggest that PTSD is associated with some performance deficits. For example, Gilbertson et al. (2001) found that Vietnam combat veterans with PTSD performed significantly worse and demonstrated more performance deficits in executive functioning based on their performance on the *Wisconsin Card Sorting Test* (*WCST*; Berg, 1948; Grant & Berg, 1948; Heaton, Chelune, Talley, Kay, & Curtiss, 1993) compared to those without PTSD. However, unlike attention and memory, executive functioning was not an independent predictor of PTSD group membership. Likewise, Koso and Hansen (2005) found significant performance deficits in executive functioning among Bosnian combat veterans with PTSD as compared to war veterans without PTSD. Sutker, Vasterling, Brailey, and Allain (1995) also found that among a sample of World War II and Korean War combat veterans who were prisoner of war survivors, PTSD was associated with impairment in executive functioning abilities such as anticipation, planning, and use of feedback on the *WCST* and the Booklet Form of Category Test (DeFillippis, McCampbell, & Rogers, 1979; Halstead, 1947; Reitan & Wolfson, 1993). Despite these findings, exactly how or to what degree PTSD may interact with other domains of neuropsychological functioning (e.g., attention) to produce deficits in executive functioning remains unclear.

Language

Language represents a collection of cognitive functions including comprehension, articulation, naming, reading, writing, and verbal fluency, all of which can be impaired by damage to different regions of the brain (Hebben & Milberg, 2002; Lezak, 2004). Previous research suggests that basic language functions such as comprehension, repetition, and spontaneous speech are unlikely to be impaired by PTSD (Vasterling & Brailey, 2005; Vasterling & Kleiner, 2005). For instance, Gurvits et al. (1993) did not detect any deficits in basic language functions among Vietnam combat veterans compared to those without PTSD, suggesting that basic language functions are left intact.

With regard to verbal fluency, however, several studies have found PTSD to be associated with performance deficits (e.g., Vasterling & Brailey, 2005). Two types of verbal fluency often are assessed on neuropsychological evaluation: (1) letter (or phonemic) verbal fluency which requires subjects to generate words that begin with a particular letter of the alphabet, and (2) category (or semantic) verbal fluency which requires subjects to generate words that belong to a particular category (e.g., animals) (Lezak et al., 2004). For instance, Uddo et al. (1993) found that Vietnam combat veterans with PTSD demonstrated impaired semantic verbal fluency performance by generating significantly fewer animal names compared to a control group of Army National Guard enlistees without PTSD. Neuropsychological performance deficits also have been found with phonemic verbal fluency. While not specific to the combat veteran population, Gil et al. (1990) found that compared to control subjects, patients with PTSD performed significantly worse on a measure of phonemic verbal fluency. Likewise, Bustamante, Mellman, David, and Fins (2001) found performance deficits in phonemic verbal fluency among trauma survivors who developed PTSD when comparing their baseline performance to their performance on reevaluation six weeks later.

Collectively, these findings suggest that while PTSD may not impair basic language abilities, other areas of language functioning such as verbal fluency may be more sensitive to the disorder. In addition, impairment in executive functioning may be partially underlying these observed performance deficits in verbal fluency (Vasterling & Kleiner, 2005). Scholars (e.g., Cummings & Miller, 2007; Hebben & Milberg, 2002; Malloy et al., 2008) conceptualized performance on fluency tests as being influenced by executive functioning abilities because these tasks reflect an individual's ability and volition to generate responses as well as maintain a set while adhering to specific criteria and rules (e.g., no listing proper names). Thus, observed performance deficits in verbal fluency may not necessarily represent pure language deficits, but may instead reflect overlapping impairment in executive functioning associated with PTSD.

Visuospatial Functioning

Intact visuospatial processing involves both a "what" (i.e., correctly identifying stimuli) as well as a "where" (i.e., location in space) component (Strauss et al., 2006). It is one domain of neuropsychological functioning that seems to be left relatively intact among individuals with PTSD (Vasterling & Brailey, 2005). For example, multiple studies (Uddo et al., 1993; Yehuda et al., 1995) failed to detect significant visuospatial performance differences when comparing combat veterans with PTSD to control groups without PTSD. Furthermore, the few studies that found significant visuospatial performance deficits (Gilbertson et al., 2001; Gurvits et al., 2002) also found that these deficits decreased substantially when controlling for pre-trauma variables (e.g., premorbid intelligence), accounted for a small percentage of the overall variance, and did not discriminate PTSD group membership. Collectively, the results suggest that visuospatial functioning is a domain of neuropsychological functioning that appears to be left relatively intact in combat veterans with PTSD.

Motor Functioning

Motor functioning is another domain of neuropsychological functioning that appears to remain relatively intact in individuals with PTSD (Vasterling & Brailey, 2005). More specifically, the one identified study that examined the effects of PTSD on motor functioning (Sullivan et al., 2003) failed to detect significant differences in motor performance between Gulf War combat veterans with and without PTSD. While few studies have focused directly on motor functioning in combat veterans with PTSD, indirect ways to observe this domain have been noted. More specifically, examining performance on a construction task can offer some insight into motor functioning because constructional ability has a motor functioning component in addition to perception and visuospatial elements (Fischer and Loring, 2004). Importantly though, as task complexity increases, the ability to identify specific motor deficits decreases.

Intellectual Functioning

Intelligence is not a unitary construct, but rather is the product of multiple interrelated cognitive processes and functional abilities (Lezak et al., 2004). As Vasterling and Brailey (2005) discussed, few studies have comprehensively assessed the array of cognitive functions that comprise intellectual functioning in individuals with PTSD. Instead, many studies assessed estimated verbal intellectual performance among individuals already diagnosed with PTSD. For example, the Information and Vocabulary subtests of the *Wechsler Adult Intelligence Scale* (*WAIS*) are widely considered to provide good estimates of premorbid intellectual functioning because they are tasks in which performance is relatively spared after brain injury or psychopathology onset (Groth-Marnat, 2003; Lezak et al., 2004). Word-list reading tasks also provide an estimate of premorbid cognitive ability (Beaumont, 2008).

Although some studies (Koso & Hansen, 2005, Sullivan et al., 2003) found no significant differences in estimated premorbid intellectual functioning associated with PTSD, the literature generally found an association between PTSD and lower premorbid intellectual functioning (Vasterling & Brailey, 2005). For instance, multiple studies (Gilbertson et al., 2001; Gurvits et al. 2002; Vasterling et al., 2002) found that Vietnam combat veterans with PTSD performed significantly lower than Vietnam combat veterans without PTSD on several subtests of the *WAIS-R* (Wechsler, 1981) that were used to estimate general cognitive ability or Intelligence Quotient (IQ). Similar results were found among Gulf War combat veterans with PTSD (Vasterling et al., 1998).

There is debate in the literature as to whether lower intellectual functioning observed in combat veterans with PTSD is a consequence of the disorder or a preexisting factor that places combat veterans at greater risk for developing PTSD (Vasterling et al., 2002). Although the intellectual functioning performance of combat veterans with PTSD often fell within the average range across studies, it still was significantly lower than that of combat veterans without PTSD. Vasterling et al. (2002) suggested that although combat veterans with PTSD may not demonstrate actual intellectual impairments, they still possess less overall intellectual resources compared to combat veterans without PTSD. Further, greater intellectual resources and sophistication may serve as a protective factor against developing PTSD (Vasterling, Brailey, Constans, Borges, & Sutker, 1997). Macklin et al. (1998) also concluded that PTSD does not decrease premorbid intelligence, but that lower premorbid intelligence increases combat veterans' risks of developing PTSD.

Another critical issue concerns premorbid intellectual functioning and level of combat exposure. Specifically, it has been suggested that combat veterans with lower premorbid intellectual abilities are assigned to heavier combat duties relative to combat veterans with higher intellectual functioning, which may increase their likelihood of developing PTSD due to greater combat exposure (Vasterling & Brailey, 2005). However, numerous studies (e.g., Macklin et al., 1998; McNally & Shin, 1995; Vasterling et al., 2002) have found that even after controlling for the level and intensity of combat exposure, premorbid intellectual functioning still was associated with current PTSD severity and accounted for a significant amount of the variance in PTSD symptoms.

Collectively, these results indicate that lower intellectual functioning is associated with PTSD in combat veterans. The evidence also suggests that, as a matter of directionality, it is not PTSD that impairs intellectual functioning. Rather, it seems that lower premorbid intellectual functioning serves as a risk factor that increases vulnerability for developing PTSD among combat veterans (Macklin et al., 1998; Vasterling et al., 1997).

General Summary of PTSD and Neuropsychological Functioning

This review of the literature generally supported the conclusion that PTSD is associated with impairment in multiple domains of neuropsychological functioning among combat veterans. Attention and memory consistently emerged as two key areas of neuropsychological functioning that seem to be the most impaired (Vasterling & Brailey, 2005). As Gilbertson and colleagues' (2001) findings indicated, measures of attention and memory together explained approximately 61% of the discrimination between Vietnam combat veterans with and without PTSD. In addition to attention and memory, evidence suggests that PTSD also is associated with performance deficits in executive functioning (Koso & Hansen, 2005; Sutker et al., 1995).

Further, while basic language abilities appear unaffected by PTSD, evidence suggests that the disorder is associated with impairment in verbal fluency (Gil et al., 1990; Uddo et al., 1993; Vasterling & Brailey, 2005). Finally, PTSD, as well as its resulting symptoms, has the potential to persist for decades and even lifetimes (Friedman, 1988; Yule, 2001).

The literature also suggests that some domains of neuropsychological functioning are left intact. For example, simple visuospatial and psychomotor functioning are relatively spared with PTSD (Gurvits et al., 2002; Sullivan et al., 2003). Furthermore, while lower premorbid intellectual functioning appears to be associated with PTSD, the evidence suggests that it is more likely that lower premorbid intellectual functioning is a risk factor that increases vulnerability for developing PTSD as opposed to a direct consequence of the disorder (Macklin et al., 1998; McNally & Shin, 1995; Vasterling et al., 1997). Collectively, these results document that PTSD is associated with impairment in neuropsychological functioning and also provide a comprehensive clinical picture of the specific domains of functioning most likely to be affected by PTSD on neuropsychological assessment based on previous cohorts of combat veterans. However, as discussed in the next section, the current wars in Afghanistan and Iraq present new challenges for understanding the neuropsychological sequelae of PTSD, particularly because of the high prevalence of comorbid mild TBI among combat troops and veterans.

Afghanistan and Iraq: The New Battlefronts

As discussed above, PTSD is associated with a range of neuropsychological impairments across multiple domains of cognitive functioning among previous cohorts of combat veterans. However, the novel and somewhat unique nature of the current wars in Afghanistan and Iraq present new challenges for understanding the neuropsychological consequences of PTSD among this emerging generation of US combat troops and veterans. In this section, I discuss key differences between the wars in Afghanistan and Iraq and previous military conflicts with particular emphasis placed on combat-related blast injuries and resulting traumatic brain injuries.

The current wars in Afghanistan and Iraq are not the “largest or the bloodiest of the conflicts that the United States has fought” (Sollinger et al., 2008, p. 21), yet, they remain distinct from past military operations (Fontana & Rosenheck, 2008; Grieger & Benedek, 2006; Tanielian, Jaycox, Adamson, & Metscher, 2008). Unlike the Vietnam War, no draft was instituted, meaning that the 1.64 million troops deployed to Afghanistan and Iraq since October 2001 are either active duty troops or reservists (Grieger & Benedek, 2006; Sollinger, Fisher, & Metscher, 2008; Tanielian & Jaycox, 2008). Further, the practice of deploying troops more frequently and for extended periods in Afghanistan and Iraq has resulted in increased combat-related trauma exposure rates among troops (Grieger & Benedek, 2006; Lew et al., 2008; Tanielian, Jaycox, Adamson et al., 2008).

Perhaps the most salient difference between these wars and previous U.S. military conflicts are combat-related injuries sustained by troops, particularly those injuries resulting from high-powered blasts (Belanger et al., 2009; Darkins, Cruise, Armstrong, Peters, & Finn, 2008; Sollinger et al., 2008). In contrast to past military conflicts where attacks typically involved firearms or grenades, enemy combatants and insurgents in the current wars frequently use powerful blast weapons such as improvised explosive devices (IEDs), mortar shells, landmines, and car and suicide bombings in their attacks against U.S. combat troops (Grieger & Benedek, 2006; Sayer et al., 2008). While the use of explosive devices is not new to these wars, the explosive and other dangerous materials in the actual devices has increased, resulting in greater power and potential to cause serious and sometimes fatal injuries (Belanger et al., 2009; Sammons & Batten, 2008; Warden, 2006). Blast-related injuries have become the hallmark injury of these wars and account for the majority of injuries sustained by United States combat troops (Belanger et al., 2009; Gondusky & Reiter, 2005; Sayer et al., 2008). For example, one study found that approximately 78% of OIF combat troops wounded in action and seeking medical treatment in Iraq were injured by IEDs or mortar attacks (Murray et al., 2005). Likewise, Gondusky and Reiter (2005) examined 32 separate attacks on a mechanized battalion in Iraq and found that 97% of combat troops that sustained injury were injured by either an IED or mortar attack. Sayer et al. (2008) also reported that 56% of service members receiving treatment at a VA polytrauma rehabilitation center were injured by a blast.

The injuries resulting from explosive blasts are classified as primary, secondary, tertiary, or quaternary. Primary blast injuries occur when energy waves resulting from a blast travel through air and water and pass through the body. These powerful waves are believed to cause overpressurization by sharply increasing the difference between atmospheric pressure and internal body pressure. It has been noted that overpressurization associated with primary blast waves can cause serious damage primarily to the hollow, air-filled organs such as the lungs, tympanic membranes, and gastrointestinal tract, despite no obvious external damage, though the potential resulting damage to other organ systems, including the brain, is less clear (DePalma, Burris, Champion, & Hodgson, 2005; Elsayed, 1997; Kocsis & Tessler, 2009; Mayorga, 1997). Secondary blast injuries result from debris, and metal or other fragments that are propelled by the explosion and result in penetrating injuries. Most blast-related deaths occur from these secondary injuries. Tertiary blast injuries occur when an individual is thrown through the air or against a stationary object by the blast which can cause head and numerous other bodily injuries as the head and body strike hard objects as they land. Finally, quaternary blast injuries refer to blast injuries that are not accounted for by primary, secondary, or tertiary blast injuries such as burns or exposure to toxins (DePalma et al., 2005).

While blast-related trauma can result in serious bodily injury, more advanced equipment such as Kevlar body armor and helmets as well as increased medical technology and response time in combat zones have resulted in numerous seriously injured OEF/OIF combat troops surviving injuries that in all likelihood would have been fatal in previous wars (Darkins et al., 2008; Grieger & Benedek, 2006; Warden, 2006). To place the impact of improved body armor and medical technology into a historical perspective, the percentage of soldiers who died from wounds sustained in combat was approximately 23% during World War II and 17% during the Vietnam War compared to approximately 9% in the current wars in Afghanistan and Iraq (Eastridge, Jenkins, Flaherty, Schiller, & Holcomb, 2006). Despite lower overall mortality rates, exposure to a blast often results in numerous bodily injuries, particularly injuries to the areas unprotected by armor such as the extremities, head, and neck areas as body armor and helmets cannot fully protect all parts of the body from blast-related injuries (Belanger et al., 2009; Okie, 2005; Sollinger et al., 2008; Xydakis, Fravell, Nasser, & Casler, 2005). For instance, Darkins and colleagues (2008) found that approximately 94% of combat troops receiving treatment at a VA polytrauma rehabilitation center sustained a head injury. Likewise, TBI rates of approximately 59% have been reported among wounded combat troops screened at Walter Reed Army Medical Center with the majority of these TBIs (68%) resulting from blast exposure in Iraq or Afghanistan (Okie, 2005; Warden et al., 2005). Because of the high prevalence of TBI among OEF/OIF combat troops serving in Afghanistan and Iraq, it often is referred to as the "signature wound" (p. 2609) of this war (Okie, 2006).

Traumatic Brain Injury: An Overview

Traumatic Brain Injury (TBI) is described as damage to the brain resulting from head trauma caused by one or more common etiologies such as motor vehicle accidents, falls, sports-related injuries, or blunt force trauma to the skull (Crooks, Zumsteg, & Bell, 2007; Michigan Department of Community Health, 2009). TBI can occur to any area of the head and are classified as either open injuries when the integrity of the skull has been penetrated or crushed (e.g., bullet wounds), or closed injuries when the skull is left intact (Aharon-Peretz & Tomer, 2007; Lucas & Addeo, 2008).

TBIs are classified as mild, moderate, or severe, with the term concussion often being used interchangeably with mild TBI (Lucas & Addeo, 2008). One measure often used to assess the severity of TBI is the Glasgow Coma Scale, which classifies TBIs as being (1) mild; (2) moderate; or (3) severe, based on a numerical score ranging from 3-15 derived from the patient's verbal, eye opening, and motor responses. Specifically, scores of 8 or lower are classified as severe TBI, 9-12 as moderate TBI, and 13-15 as mild TBI (Lucas & Addeo, 2008; Teasdale & Jennett, 1974). A criticism of the GCS is that its sensitivity is not as robust when examining milder TBIs compared to more severe brain injury. More recently Malec and colleagues (2007) developed the Mayo Classification System for Traumatic Brain Injury Severity, which classifies TBIs as being (1) Moderate-Severe (Definite) TBI; (2) Mild (Probable) TBI; or (3) Symptomatic (Possible) TBI. While TBI severity exists along a continuum, the majority of TBIs sustained both in the general population as well as among OEF/OIF combat veterans fall in the mild range (Centers for Disease Control and Prevention, 2003; McCrea, Kelly, Randolph, Cisler, & Berger, 2002; Tanielian, Jaycox, Adamson et al., 2008).

TBI Prevalence

It is difficult to estimate accurate rates of mild TBI in the general population because many individuals who experience these injuries are not hospitalized and do not receive treatment (Crooks et al., 2007). In fact, the number of mild TBIs that have been unaccounted for has been estimated to be as high as 25% (Langlois, Rutland-Brown, & Thomas, 2006). In addition to potential underreporting, mild TBI has not been conceptualized consistently by researchers and healthcare professionals, which has also made it difficult to obtain accurate mild TBI rates. For instance, some epidemiological studies defined mild TBI more narrowly as involving a loss of consciousness whereas others defined it more broadly to include loss of consciousness or altered mental status (Ramchand, Karney, Osilla, Burns, & Calderone, 2008). Among civilians in the general U.S. population, annual incidence rates of TBI have been estimated at 1.4 million by the Centers for Disease Control and Prevention (CDC), with the majority resulting from falls (28%), motor vehicle accidents (20%), being stuck by/against events (19%), and assaults (11%) (Langlois et al., 2006). Of these 1.4 million TBIs sustained annually, 75% of them are estimated to be mild TBIs (CDC, 2003). The prognosis for mild TBI generally is positive with most patients recovering within one month to one year, though approximately 10-20% of individuals with mild TBI continue to experience symptoms (Belanger, Curtiss, Demery, Lebowitz, & Vanderploeg, 2005b; Lucas & Addeo, 2008; Michigan Department of Community Health, 2009; Ruff, 2005).

Similar to the civilian population accurate TBI rates also are difficult to assess among OEF/OIF combat veterans because many combat troops who sustain a mild TBI do not seek medical attention and because of varying definitions of and diagnostic criteria for mild TBI (Helmick, 2010; Ramchand et al., 2008). For example, in one study, Schell and Marshall (2008) reported that 57% of OEF/OIF combat veterans who screened positive for a probable TBI while deployed never were evaluated by a physician. Further, variable TBI rates have been found due to differing operational definitions used by researchers. For instance, in a recent survey of 1,965 OEF/OIF combat veterans, Schell and Marshall (2008) found that 19% reported experiencing a probable TBI during their deployment in Afghanistan or Iraq when TBI was defined as any alteration of consciousness including loss of consciousness. In a similar study Hoge and colleagues (2008) found that approximately 15% of OEF/OIF combat troops sustained an injury that resulted in either loss of consciousness or altered mental status. Vasterling et al. (2006) reported mild TBI rates of approximately 7.6% among deployed troops when using loss of consciousness of greater than fifteen minutes as criteria for mild TBI.

Importantly, mild TBI resulting from combat exposure in a warzone is somewhat distinct from the TBIs encountered in most civilian populations (Warden, 2006). Specifically, combat-related mild TBI in Afghanistan and Iraq is complicated by increased chances of sustaining more than one TBI because of greater risk of exposure to enemy attacks over extended and multiple deployments (Helmick et al., 2006; Hoge et al., 2008; Tanielian & Jaycox, 2008). In the most extreme case, sustaining multiple head injuries over a relatively short period of time before the primary injury fully heals can lead to a potentially fatal condition known as second impact syndrome (Lucas & Addeo, 2008). In addition, the effects of TBIs also can impact many important areas of military functioning such as the ability to drive a vehicle, follow orders, handle firearms, or self-regulate emotions (Helmick et al., 2006; Lew et al., 2008). The one-year health care costs associated with mild TBI alone are estimated at between $27,259 and $32,759 per individual (Tanielian & Jaycox, 2008). Finally, mild TBI may be further complicated in some OEF/OIF combat troops and veterans in that it can co-occur with PTSD (Lew et al., 2008).

Because the current wars in Afghanistan and Iraq are producing combat veterans suffering from both of these "invisible wounds" of war (Tanielian & Jaycox, 2008, p. 7), one can question whether the neuropsychological functioning of OEF/OIF combat veterans with PTSD may be different from what has previously been found with past cohorts of combat veterans with uncomplicated PTSD.

PTSD and TBI: Polytrauma OEF/OIF Veterans

According to the Veterans Health Administration Handbook (2005), polytrauma is defined as "two or more injuries to physical regions or organ systems, one of which may be life threatening, resulting in physical, cognitive, psychological, or psychosocial impairments and functional disability" (p. 3). As such, combat veterans with both PTSD and TBI meet polytrauma criteria by the VA healthcare system. The first polytrauma patient with combat-related injuries was admitted into the VA healthcare system in January 2002 (Sigford, 2008). Since that time, the VA has established four regional Polytrauma Centers as well as 21 Polytrauma Network Sites to meet the healthcare and treatment needs of the growing population of OEF/OIF polytrauma patients (Lew et al., 2007). While numerous combinations of injuries sustained during combat can result in polytrauma status among OEF/OIF combat veterans, the remainder of this review focuses on the combination of PTSD and TBI.

Some scholars have questioned whether PTSD can exist following a TBI especially if a pronounced period of unconsciousness occurs as this loss of consciousness can prevent the individual from fully experiencing and forming a memory of the traumatic event (Glaesser, Neuner, Lutgehetmann, Schmidt, & Ebert, 2004; Harvey, Kopelman, & Brewin, 2005; Karney et al., 2008). OEF/OIF combat troops, on the other hand, are at an increased risk for experiencing repeated traumatic stressors and events by being stationed in an active combat zone so that multiple opportunities for trauma exposure exist independent of any specific incident that may have resulted in a TBI (Vasterling, Verfaellie, & Sullivan, 2009; Tanielian & Jaycox, 2008). As such, King (2008) concluded that not only can TBI and PTSD diagnoses co-occur, but the evidence suggests that sustaining a mild TBI may actually increase one's overall risk of developing PTSD. For example, one study found that approximately one-third of combat veterans with a probable TBI met criteria for probable PTSD (Schell & Marshall, 2008). Hoge and colleagues (2008) found PTSD rates of approximately 44% among OEF/OIF combat troops who sustained a head injury that resulted in loss of consciousness compared to 9% of uninjured troops. Similarly, Lew and colleagues (2007) reported that 42% of OEF/OIF veterans with a mild TBI also displayed symptoms of PTSD at post-deployment screening. Collectively, the current evidence supports the two conclusions: (1) PTSD and mild TBI can coexist as comorbid conditions and (2) a notable population of OEF/OIF combat troops and veterans experience these comorbid conditions (Hoge et al., 2008; Vasterling et al., 2009).

Scholars also have noted that comorbid PTSD and TBI presents several diagnostic and treatment challenges because the resulting symptoms are not exclusive to just one of the conditions (Bryant, 2001; Lew et al., 2008; Tanielian & Jaycox, 2008). More specifically, problems with attention, concentration, and memory are common symptoms of both PTSD as well as mild TBI as independent conditions (Burnam et al., 2008; Helmick et al., 2006; Warden, 2006). For example, reported changes in mental status in a combat zone also can be attributed to dissociative symptoms and altered consciousness associated with the acute psychological stress and trauma associated with being in a combat zone or the cognitive sequelae of TBI, sometimes with no clear etiological distinction present on a later symptom screening (Brenner et al., 2009; Hoge et al., 2008). Further, mild TBIs typically are not detectable when using most traditional neuroimaging techniques (Lew et al., 2008; Malec et al., 2007). As such, it may be difficult to separate which symptoms result from PTSD versus mild TBI (Hill, Mobo, & Cullen, 2009). For instance, Brenner and colleagues (2010) found no significant differences between combat veterans with blast-related mild TBI and PTSD versus those with blast-related mild TBI without PTSD on neuropsychological testing. Despite the symptom overlap, preliminary evidence suggests that once PTSD symptoms were controlled for, mild TBI did not remain significantly associated with current symptoms among combat soldiers returning from Iraq (Hoge et al., 2008). Belanger and colleagues (2010) also concluded that many self-reported mild TBI symptoms may result from emotional distress after controlling for PTSD symptom severity among mild TBI patients.

Comorbid PTSD and TBI also may have complicated reciprocal implications that impact the course and recovery of the conditions as well as associated impairment and long term consequences (Karney et al., 2008; Lew et al., 2008; Vasterling et al., 2009). More specifically, TBI can affect both cognitive and emotional functioning resources that may be necessary to effectively cope with PTSD symptoms. For example, Vanderploeg, Belanger, and Curtiss (2009) found that PTSD recovery was negatively impacted among patients who sustained a subsequent mild TBI. On the other hand, PTSD can lead to overall cognitive dysfunction as well as difficulties with sleep disturbances because of nightmares and reexperiencing symptoms, which can impact healing from a brain injury (Lew et al., 2008; Michigan Department of Community Health, 2009; Wolf & Charney, 1991). Therefore, effective treatment of comorbid PTSD and mild TBI likely will require a better understanding of neuropsychological sequelae and functional implications of this diagnostic combination (Warden, 2006). Furthermore, as Brenner, Vanderploeg, and Terrio (2009) noted, it often is not possible to tease apart the specific percentage of symptoms due to comorbid conditions. This position echoes a recent Department of Defense Task Force on Mental Health (2007) report that indicated that addressing the symptoms of PTSD and TBI as co-occurring conditions may prove more important than differential diagnoses. Practically speaking, this would require greater integration between agencies and clinics that traditionally focused on PTSD and facilities treating TBI in order to better understand the relationship between PTSD and TBI and to provide more comprehensive treatment for this increasing population of OEF/OIF combat veterans (Lew et al., 2008). Addressing the call from the Department of Defense, the present study examined whether the neuropsychological functioning of OEF/OIF combat veterans who suffer from the combination of PTSD and mild TBI significantly differs from that of combat veterans with uncomplicated PTSD across the central domains of neuropsychological functioning previously discussed.

Chapter 3

Method

Participants

The medical records and neuropsychological assessment data of 125 OEF/OIF combat veterans with PTSD (*n* = 59) and PTSD and comorbid mild TBI (*n* = 66) who received outpatient neuropsychological assessment and evaluation services at a Neuropsychology Clinic in a VA Medical Center/Polytrauma Rehabilitation Local Support Site were reviewed and included for analysis in the present study. All OEF/OIF combat veterans included in this study received a comprehensive neuropsychological evaluation using a flexible battery approach that assessed the seven central domains of neuropsychological functioning: (1) attention; (2) learning and memory; (3) executive functioning; (4) language; (5) visuospatial functioning; (6) motor functioning; and (7) intellectual functioning. The following demographic data was collected from each combat veteran's record included in this study and is presented in Table A1: gender, race/ethnicity, handedness, relationship status, military branch, and deployment location(s). An examination of the demographic variables presented in Table A1 indicated that the sample was predominately White, male, and largely composed of Army combat veterans who served in Iraq. In addition, means, standard deviations, and standard errors were calculated for age, self-reported years of education completed, length of deployment, and self-reported PTSD symptom severity as measured by the *Mississippi Scale* for each diagnostic group and are presented in Table A2.

Measures

Attention. Multiple measures that assess attention were examined and included in the analyses. First, subjects' performance on the *Letter-Number Sequencing* subtest that is found on both the *Wechsler Adult Intelligence Scale – Third Edition* (*WAIS-III*; Wechsler, 1997a) as well as the *Wechsler Memory Scale – Third Edition* (*WMS-III*; Wechsler, 1997b) was included. On this subtest, subjects hear random sequences of letters and numbers that increase in length as the test progresses and are asked to verbally produce the numbers in numerical order starting with the lowest number followed by the letters in alphabetical order (Lezak et al., 2004). Test-retest reliability for the *Letter-Number Sequencing* subtest has ranged from .70-.79 (Strauss et al., 2006).

Next, the *Digit Span* subtest that is also found on the *WAIS-III* (Wechsler, 1997a) as well as the *WMS-III* (Wechsler, 1997b) was included. The *Digit Span* subtest is a test of auditory attention span and mental manipulation where examinees are required to repeat sequences of random numbers that increase in length in both forward (*Digits Forward*) as well as in reverse (*Digits Backward*) order (Hebben & Milberg, 2002; Lezak et al., 2004). Test-retest reliability for the *Digit Span* subtest has ranged from .80-.89 (Strauss et al., 2006).

Third, subjects' performance on Part A of the *Trail Making Test* (*TMT*) from the *Halstead-Reitan Neuropsychological Test Battery* (Heaton, Miller, Taylor, & Grant, 2004; Reitan & Wolfson, 1993) was included. Part A of the *TMT* is a measure of sustained visual attention, scanning, and tracking where subjects are asked to draw a line that connects twenty-five consecutively numbered circles (Hebben & Milberg, 2002; Lezak et al., 2004). As Strauss et al. (2006) noted, the test-retest reliability coefficients for Part A of the *TMT* have ranged from .46 to .94 depending on the age of the participants and the population tested.

Fourth, subjects' performance on the *Ruff 2 & 7 Selective Attention Test* (Ruff & Allen, 1996) was included for analysis. The *Ruff 2 & 7 Selective Attention Test* is a visual search and cancellation task where subjects must identify target numbers (2's and 7's) imbedded among either other distractor letters (*Automatic Search*) or numbers (Controlled Search) across 20 trials lasting fifteen seconds each for a total of five minutes (Hebben & Milberg, 2002; Strauss et al., 2006). This test measures both sustained and selective attention and produces six scores: (1) Automatic Detection Speed; (2) Automatic Detection Accuracy; (3) Controlled Search Speed; (4) Controlled Search Accuracy; (5) Total Speed; and (6) Total Accuracy (Ruff & Allen, 1996). Test-retest reliability coefficients also were found to be greater than or equal to .80 for all scores on this measure with the exception of the Automatic Detection Accuracy score for which test-retest reliability coefficients ranged between .70-.79 (Ruff & Allen, 1996; Strauss et al., 2006).

Learning and Memory. Two measures that assessed learning and memory were examined and included for analysis. First, subjects' performance scores on the *California Verbal Learning Test – Second Edition* (*CVLT-II*; Delis, Kramer, Kaplan, & Ober, 2000) were included as a measure of verbal learning and memory. As Hebben and Milberg (2002) indicated, the *CVLT-II* is a word list learning task that assesses verbal learning and memory and "provides information about acquisition, recall, retention, and retrieval of verbal information" (p. 110). On this test, subjects are read a list (List A) of sixteen words that can be grouped into four semantic categories in random order and asked to recall the words from this list in any order across 5 trials. Next, subjects are presented with a second, interference list (List B) followed by a free recall trial of this list. Subjects are then asked to recall words from List A after both a short delay as well as a long delay. Finally, subjects a presented with a recognition paradigm where they must correctly identify and distinguish words from List A with nonlist words (Hebben & Milberg, 2002; Lezak et al., 2004). As Lezak et al. (2004) noted, the *CVLT-II* can produce at least 19 separate scores. In the present study, the following 9 specific scores were included in the analyses: (1) Trials 1-5 Total Correct; (2) Total Learning Slope Trials 1-5; (3) Short Delay Free Recall (4) Long Delay Free Recall; (5) Proactive Interference; (6) Retroactive Interference;

(7) Long Delay Yes/No Recognition Hits; (8) Long Delay Yes/No Recognition False Positives; and (9) Total Intrusions. Test-retest reliability coefficients for these selected scores generally have been adequate and have ranged as follows: ≤.59 (Total Learning Slope Trials 1-5); .60-.69 (Total Intrusions); .70-.79 (Long Delay Yes/No Recognition Hits, Long Delay Yes/No Recognition False Positives); .80-.89 (Trials 1-5 Total Correct, Short Delay Free Recall, Long Delay Free Recall) (Delis et al., 2000; Strauss et al., 2006).

Second, subjects' performance on the *Rey Complex Figure Test* (*RCFT*; Meyers & Meyers, 1995; Osterrieth, 1944; Rey, 1941) was examined and included for analysis. The *RCFT* is a commonly used neuropsychological instrument that assesses visuospatial constructional ability, perceptual organization, immediate and delayed visual memory, and recognition (Hebben & Milberg, 2002; Lezak et al., 2004; Strauss et al., 2006). On this test, subjects first are presented with a complex geometric figure and instructed to copy it on a blank sheet of paper. They then are asked to reproduce the figure from memory on a blank sheet of paper three minutes later (Immediate Recall) and 30 minutes later (Delayed Recall). Finally, the test concludes with a recognition trial (Hebben & Milberg, 2002). As scholars (e.g., Levine, Miller, Becker, Selnes, & Cohen, 2004; Meyers & Meyers, 1995) have discussed, the range for several *RCFT* scores such as the Copy Trial is restricted because of near maximum performance by unimpaired subjects. As such, test-retest reliability coefficients have been calculated for the following scores with sufficient range: Immediate Recall, r = .76; Delayed Recall, r = .89; and Recognition Total Correct, r = .87 (Meyers & Meyers, 1995).

Executive Functioning. Two measures of executive functioning were examined and included for analysis. First, subjects' performance on Part B of the *Trail Making Test* (*TMT*) from the *Halstead-Reitan Neuropsychological Test Battery* (Heaton et al., 2004; Reitan &

Wolfson, 1993) was included for analysis. Part B of the *TMT* is a measure of complex visual tracking and sequencing and cognitive flexibility where subjects are asked to draw a line that connects a sequence of numbered and lettered circles in alternating order (i.e., connect the number 1 to the letter A, connect the letter A to the number 2, and so forth) (Hebben & Milberg, 2002; Lezak et al., 2004; Reitan & Wolfson, 1993). As Strauss et al. (2006) indicated, test-retest reliability coefficients for Part B of the *TMT* generally have been adequate and have ranged above .70.

Second, subjects' performance on the *Wisconsin Card Sorting Test* (*WCST*; Berg, 1948; Grant & Berg, 1993; Heaton et al., 1993) was included for analysis. The *WCST* is regarded as a task of executive functioning that measures abstract reasoning, concept formation, problem solving, ability to maintain and shift set, and ability to learn from feedback (Heaton et al., 1993; Hebben & Milberg, 2002; Lezak et al., 2004). On this task, subjects are presented with stimulus cards and are instructed to match cards from a deck to one of the stimulus cards. The subject is not told what the correct sorting pattern is, but is told whether their response was "correct" or "incorrect" after each trial. Once subjects have deduced the correct sorting rule, the sorting rule is then changed to examine whether the subject can detect the new sorting rule and respond according (Beaumont, 2008; Lezak et al., 2004). In this study, the following 8 *WCST* scores were examined: (1) Total Errors; (2) Perseverative Responses; (3) Perseverative Errors; (4) Non-Perseverative Errors; (5) Conceptual Level Responses; (6) Categories Completed; (7) Failures to Maintain Set; and (8) Trials Administered (Total Cards). Estimates of test-retest reliability for the *WCST* have ranged from unacceptably low to good across multiple studies (Strauss et al., 2006). However, as Lezak et al. (2004) noted, in many ways the *WCST* is a "one-shot test" (p. 588) in that once subjects with unimpaired memory deduce the correct sorting and changing patterns, they are unlikely to fail the test again. Thus, the test is no longer a reliable measure of problem solving ability.

Language. The *Verbal Fluency* test of the *Delis-Kaplan Executive Function Systems* (*D-KEFS*; Delis, Kaplan, & Kramer, 2001) instrument was examined to analyze both phonemic and semantic verbal fluency. In condition 1 (letter fluency), subjects are given a letter of the alphabet and are instructed to verbally produce as many words as possible beginning with the selected letter within a one-minute time limit. In condition 2 (category fluency), subjects are instructed to verbally produce as many words as possible that belong to a designated semantic category within a one-minute time limit. Test-retest reliability coefficients have ranged from .80-.89 for the letter fluency condition and from .70-.79 for the category fluency condition.

Visuospatial Functioning. The *Block Design* subtest on the *Wechsler Abbreviated Scale of Intelligence* (*WASI*; Wechsler, 1999) was used to assess visuospatial functioning. On this test of visuospatial organization and construction, subjects are presented with two, four, or nine blocks depending on the design to be replicated. Subjects are then instructed to use the blocks that they are given to construct replicas of designs that are first constructed by the examiner and then later presented pictorially in a stimulus booklet (Fischer & Loring, 2004; Wechsler, 1999). Spilt-half reliability coefficients for the *Block Design* subtest have ranged from .80-.90 (Axelrod, 2002; Strauss et al., 2006).

Motor Functioning. The *Finger Tapping Test* (also known as the *Finger Oscillation Test*) from the *Halstead-Reitan Neuropsychological Test Battery* (Reitan & Wolfson, 1993) was examined and included as a measure of manual dexterity and motor functioning. This test requires a subject to tap a key attached to a counter device which records the number of taps in a series of ten-second tapping intervals. Performance on this test is measured on both a subject's dominant hand as well as their non-dominant hand (Lezak et al., 2004; Reitan & Wolfson, 1993). According to Strauss et al. (2006) test-retest reliability coefficients on the *Finger Tapping Test* have ranged from .58-.93.

Intellectual Functioning. The *Vocabulary* subtest that is found on the *WASI* (Wechsler, 1999) was examined and included in the present study as an estimate of subjects' premorbid intellectual functioning. This subtest broadly assesses subjects' general verbal intelligence, word knowledge, and language development, and requires subjects to verbally produce a definition to words of increasing difficulty that are presented to them (Groth-Marnat, 2003; Lezak et al., 2004). As Groth-Marnat (2003) noted, the *Vocabulary* subtest is a "rough measure of the subject's optimal intellectual efficiency" (p. 162). Further, it has been observed that performance on the *Vocabulary* subtest is least sensitive to impairment by brain injury, neurological deficits, early-stage dementia, and psychological disorders (Groth-Marnat, 2003; Hebben & Milberg, 2002; Lezak et al., 2004; Reitan & Wolfson, 1993). Spilt-half internal consistency reliability coefficients for the *Vocabulary* subtest have ranged from .80-.90 (Axelrod, 2002; Strauss et al., 2006).

Psychological Functioning. Three self-report measures that assess psychological functioning also were examined and included for analysis. First, the *Mississippi Scale for Combat-Related Posttraumatic Stress Disorder* (Keane, Caddell, & Taylor, 1988), a self-report measure of symptoms of Posttraumatic Stress Disorder (PTSD) among combat veterans was examined. This inventory contains 35 items, each of which are self-rated by combat veterans on a scale from 1 to 5 (possible total score range 35-175), where higher total scores are reflective of more severe PTSD symptoms. The *Mississippi Scale* generally was found to possess strong psychometric properties with estimates of internal consistency reliability ranging from .94-.96, and a 1-week test-retest reliability correlation of .97 for the entire scale (Keane et al., 1988; McFall, Smith, Mackay, & Tarver, 1990). Moreover, in terms of diagnostic accuracy, the *Mississippi Scale* was found to have 93% sensitivity and 89% specificity (Keane et al., 1988).

Second, the *Beck Depression Inventory-Second Edition* (*BDI-II*; Beck, Steer, & Brown, 1996) was included as a self-report measure of depressive symptoms. The *BDI-II* is a participant self-report inventory designed to measure the occurrence and severity of depression. This inventory contains 21 items, each of which are self-rated by patients on a scale from 0 to 3 where higher total scores are reflective of more severe depressive symptoms. The standard interpretation guidelines used for the *BDI-II* are as follows: 0–13: minimal depression; 14–19: mild depression; 20–28: moderate depression; and 29–63: severe depression. Estimates of internal consistency were reported at $\alpha = .91$ (Beck, Steer, Ball, & Ranieri, 1996) and test-retest reliability correlation coefficients at .93 (Beck et al., 1996).

Third, the *Beck Anxiety Inventory* (*BAI*; Beck, Epstein, Brown, & Steer, 1988) was included in the present study as a self-report measure of anxiety symptoms. This inventory contains 21 items, each of which are self-rated by patients on a scale from 0 to 3 where higher total scores are reflective of more severe symptoms of anxiety. The standard interpretation guidelines used for the *BAI* are as follows: 0–7: minimal anxiety; 8–15: mild anxiety; 16–25: moderate anxiety; and 26–63: severe anxiety. Estimates of internal consistency were reported at $\alpha = .92$ and test-retest reliability correlation coefficients over one week at .75 (Beck et al., 1988).

Procedure

All data included in the present study were initially collected from OEF/OIF combat veterans, during the period from 2005-2010 when they received comprehensive outpatient neuropsychological evaluation services at a VA Medical Center. The data consist of the neuropsychological and psychodiagnostic test results that were described previously. All OEF/OIF combat veterans whose test data will be included in this study were referred to the Neuropsychology Clinic and underwent a one-session neuropsychological evaluation that included comprehensive testing using a flexible battery approach across the seven domains of neuropsychological functioning discussed previously. All combat veterans first were interviewed and then evaluated/diagnosed after testing was completed by a licensed, doctoral-level staff neuropsychologist. All neuropsychological testing was completed by trained neuropsychology technicians, predoctoral clinical psychology interns, or an advanced counseling psychology practicum student under the direct clinical supervision of a VA staff neuropsychologist.

For step one of this study, all of the Neuropsychology Clinic's patient logbooks from 2005-2010 which document every veteran who received evaluation services were examined in order to indentify all the OEF/OIF combat veterans who received services. Once all potential OEF/OIF combat veterans' records were identified, a copy of each individual combat veteran's integrated neuropsychological evaluation report as well as their medical record accessed via the VA's Computerized Patient Record System (CPRS) were thoroughly reviewed in order to obtain the necessary demographic information and to ensure that the inclusion criteria discussed below are present and that no exclusion criteria are present.

The specific inclusion criteria used to identify potential records for the present study included the following: (1) the veteran must have been an Operation Enduring Freedom (OEF) or Operation Iraqi Freedom (OIF) veteran; (2) the veteran must have been exposed to combat; and (3) the veteran must have received a diagnosis of either (a) PTSD or (b) PTSD and comorbid mild TBI. For the purposes of this study, those OEF/OIF combat veterans included in the PTSD group did not report any injuries to the head that resulted in a loss of consciousness during their deployment. Conversely, those combat veterans included in the PTSD and comorbid mild TBI group sustained at least one traumatic injury to the head that resulted in a loss of consciousness lasting not more than 30 minutes during their deployment. According to the Mild Traumatic Brain Injury Committee of the Head Injury Interdisciplinary Special Interest Group of the American Congress of Rehabilitation Medicine (1993), the definition of a traumatic brain injury includes "1) the head being struck, 2) the head striking an object, [or] 3) the brain undergoing an acceleration/deceleration movement" (p. 86). Further, this specification that any loss of consciousness must not exceed 30 minutes is consistent with the criteria put forth by the committee for mild TBI. OEF/OIF combat veterans were excluded if their record indicates a history of a psychotic disorder, a preexisting neurological condition (e.g., multiple sclerosis) in which it was determined that the condition would negatively affect neuropsychological test performance, or a head injury that resulted in a loss of consciousness greater than 30 minutes that would classify the TBI in the moderate to severe TBI range. After all eligible OEF/OIF combat veterans' records were identified, the neuropsychological and psychodiagnostic assessment data described above were entered into a data file. In order to monitor the neuropsychological test data for accurate entry, approximately 5-10% of the cases entered into the dataset were randomly selected and rescored prior to conducting any statistical analyses.

Chapter 4

Results

Score Transformations

The neuropsychological test scores included for analysis in this study initially were expressed as *z-scores*, *t-scores*, *scaled scores*, or *standard scores* depending on the individual assessment instrument. In order to make meaningful comparisons between test scores, it was necessary for all scores to be expressed in comparable units. Therefore, all the test scores were transformed into *standard scores*. *Standard scores* often are used with IQ testing and have a mean of 100 and a standard deviation of 15 (Strauss et al., 2006). For score interpretation purposes in this study, scores of 69 and below were considered to be in the Impaired range, scores of 70-79 in the Borderline Impairment range, scores of 80-89 in the Low Average range, scores of 90-110 in the Average range, scores of 111-120 in the High Average range, and scores of 120-129 in the Superior range.

Preliminary Analyses

To determine if significant differences existed between the PTSD and PTSD and comorbid mild TBI diagnostic groups in terms of their age, self-reported years of education completed, and length of deployment, a Multivariate Analysis of Variance (MANOVA) was conducted where diagnostic group was entered as the fixed factor and age, self-reported years of education completed, and length of deployment were entered at the dependent variables. The MANOVA was significant, Wilks's $\Lambda = .86$, $F(3, 114) = 6.05$, $p = .001$. Follow-up Analyses of Variance (ANOVAs) revealed that no significant differences existed between groups in terms of either self-reported years of education completed $F(1, 116) = .02$, $p = .89$, or length of deployment $F(1, 116) = .00$, $p = .97$; however, a significant difference was detected with regard to age $F(1, 116) = 17.69$, $p < .001$, with the mean age for the PTSD (M =33.5, SD = 10.7) group being approximately six years older than the PTSD and mild TBI group (M = 27.5, SD = 4.8). A further examination of the age distributions revealed that approximately 24% of the PTSD group was at least 40 years-old whereas only approximately 2% of the PTSD and mild TBI group fell into this same age range. As such, the significant age difference between groups may be a characteristic of the sample examined in this instance. Finally, an ANOVA was performed to determine if the diagnostic groups differed significantly in terms of their self-reported PTSD symptom severity as measured by the *Mississippi Scale*. Results were nonsignificant, $F(1, 65)$ = .73, $p = .40$, which indicated that the OEF/OIF combat veterans with PTSD/mild TBI did not significantly differ from those with uncomplicated PTSD in terms of PTSD symptom severity.

Next, means, standard deviations, and standard errors were computed for all tests scores included in this study and are presented in Table A3 for the between-domains measures (i.e.- across the seven major domains of neuropsychological functioning discussed below), Tables A4-A8 for the within-domains measures, and Table A9 for the self-report measures of psychological functioning. A norms-based performance comparison of means indicated that OEF/OIF combat veterans with both uncomplicated PTSD and PTSD and mild TBI scored within the average range on the vast majority of measures included in this study. It was noted that both groups performed approximately one full standard deviation below the mean and in the low average range on both the *Trail Making Test Part A* as well as the *CVLT-II Recognition Hits* score.

Finally, bivariate correlations were computed for all test scores included in this study for each group of combat veterans and are presented in Table A10 for the between-domains measures, Tables A11-A15 for the within-domains measures, and Table A16 for the measures of psychological functioning. An examination of the correlation tables revealed that several of the measures examined in this study were significantly correlated with correlation magnitudes ranging from small to large (r = .28 - .99) (Cohen, 1988). The significant correlations found among several of the measures examined were somewhat of an expected finding considering the relative interrelatedness of the multiple domains of neuropsychological functioning examined in this study.

Examining Between-Domains Neuropsychological Functioning

Because limitations may arise when inferences are drawn from single test scores and, in some cases, differences between groups may not be obvious by observing individuals scores, it often is clinically useful to examine overall patterns or configuration of scores (Hannay & Lezak, 2004; Meehl, 1950). Therefore, given the interrelated nature of neuropsychological domains, this study used neuropsychological profiles to capture the gestalt of each group of combat veterans' cognitive functioning by examining patterns of performance across measures. First, a between-domains neuropsychological profile was constructed for each group of OEF/OIF combat veterans based on their mean scores on each of the following nine measures (see Figure B1): (1) *Letter-Number Sequencing* subtest (attention); (2) *CVLT-II Learning Slop* (learning); (3) *CVLT-II Delayed Recall* (memory); (4) *Trail Making Test Part B* (executive functioning); (5) *D-KEFS Verbal Fluency* (language); (6) *Block Design* subtest (visuospatial functioning); (7) *Finger Tapping Test* (dominant hand); (8) *Finger Tapping Test* (non-dominant hand) (motor functioning); and (9) *Vocabulary* subtest (intellectual functioning).

After the between-domains profiles were constructed, a profile analysis was conducted to determine if these profiles differed significantly between groups of OEF/OIF combat veterans. Profile analysis is a statistical technique that tests if two or more patterns of scores or profiles significantly differ by first determining whether they are parallel (i.e., equal differences between adjacent means). If the profiles are found to be parallel, then they are further analyzed to determine whether they are coincident (i.e., equal population means). Finally, if the profiles are found to be coincident, they are analyzed to determine if they are level (i.e., equal means across groups and variables) (Shelton, 1998, Stevens 2001). The nonsignificant results of the profile analysis revealed that the between-domains profiles were parallel, Wilks's Λ = .96, $F(8, 66)$ =.32, p = .96; coincident, Wilks's Λ = 1.00, $F(1,73)$ = .23, p = .64; and level, Wilks's Λ = .97, $F(8, 66)$ =.25, p = .98. Thus, the between-domains profiles did not differ significantly between the PTSD and mild TBI and PTSD groups.

Examining Within-Domains Neuropsychological Functioning

Scholars have noted that several domains of neuropsychological functioning previously discussed are multidimensional constructs comprised of several interrelated processes and components (Kramer & Quitania, 2007; Lezak et al., 2004; Vasterling & Brailey, 2005). Therefore, within-domain profiles also were constructed for the domains of attention, verbal and visual memory, executive functioning, and language. The purpose of these within domains profiles was twofold: to obtain a more nuanced understanding of OEF/OIF combat veterans' neuropsychological functioning within each of these domains and to examine whether significant within-domain differences exist between those with PTSD compared to those with PTSD and comorbid mild TBI.

Attention. A modified version of the test battery used by Vasterling and colleagues (1998; 2002) to capture the four factors of attention: (1) focus-execute; (2) shift; (3) sustain; and (4) encode (Mirsky et al., 1991) was included for analysis in this study. Specifically, mean performance on the following tests were used to create the within-domains attention profiles (see Figure B2): *Total Speed* and *Total Accuracy* scores from the *Ruff 2 & 7 Selection Attention Test* (focus-execute); *Non-Perseverative Errors* score from the *WCST* (shift); Part A of the *Trail Making Test* (sustain); and *Digit Span* subtest (encode). The nonsignificant results of the profile analysis revealed that the profiles were parallel, Wilks's $\Lambda = .91$, $F(4, 37) = .93$, $p = .46$; coincident, Wilks's $\Lambda = .97$, $F(1, 40) = 1.32$, $p = .26$; and level, Wilks's $\Lambda = .88$, $F(4, 37) = 1.29$, $p = .29$. Thus, the within-domains attention profiles did not differ significantly between groups.

Verbal Memory. Verbal learning and memory profiles were constructed for both groups of OEF/OIF combat veterans using mean performance on the following eight scores from the *CVLT-II* (see Figure B3): (1) *Trials 1-5 Correct*; (2) *Short Delay Free Recall* (3) *Long Delay Free Recall*; (4) *Proactive Interference*; (5) *Retroactive Interference*; (6) *Long Delay Yes/No Recognition Hits*; (7) *Long Delay Yes/No Recognition False Positives*; and (8) *Total Intrusions*. The nonsignificant results of the profile analysis revealed that the profiles were parallel, Wilks's $\Lambda = .96$, $F(7, 83) = .49$, $p = .84$; coincident, Wilks's $\Lambda = 1.00$, $F(1, 89) = .28$, $p = .60$; and level, Wilks's $\Lambda = .93$, $F(7, 83) = .95$, $p = .48$. Thus, the within-domains verbal memory profiles did not differ significantly between the PTSD/mild TBI and PTSD groups.

Visual Memory. Visual memory profiles also were constructed for each group of combat veterans using mean performance on the following scores from the *RCFT* (see Figure B4): (1) *Immediate Recall*; (2) *Delayed Recall*; and (3) *Recognition*. The nonsignificant results of the profile analysis revealed that the profiles were parallel, Wilks's $\Lambda = .98$, $F(2, 64) = .76$, $p = .47$; coincident, Wilks's $\Lambda = .99$, $F(1, 65) = .45$, $p = .50$; and level, Wilks's $\Lambda = .98$, $F(2, 64) = .65$, $p = .52$. Thus, the within-domains visual memory profiles did not differ significantly between the PTSD/mild TBI and PTSD groups.

Executive Functioning. Executive functioning profiles were constructed for each group of combat veterans using mean performance on the following five scores from the *WCST* (see

Figure B5): (1) *Total Errors*; (2) *Perseverative Responses*; (3) *Perseverative Errors*; (4) *Non-Perseverative Errors;* and (5) *Conceptual Level Responses*. Results of the profile analysis surpassed the statistical significance threshold and indicated that the profiles were not parallel, Wilks's $\Lambda = .90$, $F(4, 102) = 2.87$, $p < .05$.

Because the profile analysis revealed that the profiles were not parallel, a follow-up discriminant analysis was performed. As expected given the non-parallel *WCST* profiles, results of the discriminant analysis revealed that mean performance on all five scores was not equal between groups. More specifically, mean *Perseverative Responses* scores significantly differed between diagnostic groups, Wilks's $\Lambda = .97$, $F(1, 105) = 3.80$, $p = .05$. However, no significant differences between diagnostic groups were detected on the other four *WCST* scores examined: *Total Errors*, Wilks's $\Lambda = .99$, $F(1, 105) = .77$, $p = .38$; *Perseverative Errors*, Wilks's $\Lambda = .97$, $F(1, 105) = 3.62$, $p = .06$; *Non-Perseverative Errors*, Wilks's $\Lambda = .99$, $F(1, 105) = 1.04$, $p = .31$, and *Conceptual Level Responses*, Wilks's $\Lambda = .99$, $F(1, 105) = .78$, $p = .38$. Interestingly, while the *Perseverative Responses* scores differed significantly between groups, a further examination of each group’s mean performance revealed that neither group demonstrate impaired (or even average) performance as both groups scored in the high average range, PTSD group ($M = 111.0$, $SD = 21.8$) PTSD/mild TBI group ($M = 119.0$, $SD = 20.5$). Moreover, contrary to expectation, the PTSD/mild TBI group actually performed better compared the PTSD group. Thus, while technically significant from a statistical standpoint, this single finding may be an artifact of the particular sample examined and likely would be of little clinical utility. Finally, because the *WCST* profiles were found not to be parallel, they were not analyzed further to determine if they were coincident or level.

In addition to the five *WCST* scores discussed above, the *Categories Completed*, *Failures to Maintain Set*, and *Trials Administered* scores also were examined. Unfortunately, because these three scores are expressed only as raw scores and are unable to be converted into *standard scores*, they were not able to be included in the *WCST* profile analysis discussed above. Instead, a separate MANOVA was conducted where diagnostic group was entered as the fixed factor and these three *WCST* scores were entered as the dependent factors in order to determine if significant differences existed. The MANOVA was not significant, Wilks's $\Lambda = .98$, $F(3, 103) = .85$, $p = .47$, suggesting that OEF/OIF combat veterans with PTSD and comorbid mild TBI did not differ significantly from those with uncomplicated PTSD on either of these three *WCST* scores.

Language. Finally, within-domain language profiles that examined both phonemic and semantic verbal fluency using mean performance on the *Letter* and *Category Fluency* subtests of the *D-KEFS* were constructed for each group of OEF/OIF combat veterans (see Figure B6). The nonsignificant results of the profile analysis revealed that the profiles were parallel, Wilks's $\Lambda = 1.00$, $F(1, 96) = .35$, $p = .56$; coincident, Wilks's $\Lambda = 1.00$, $F(1, 96) = .01$, $p = .94$; and level, Wilks's $\Lambda = 1.00$, $F(1, 96) = .01$, $p = .94$. Thus, the within-domains language profiles did not differ significantly between the PTSD/mild TBI and PTSD groups.

Predicting Diagnostic Group Membership

A previous study by Gilbertson et al. (2001) found that PTSD group membership could be independently predicted by performance on tests of attention and memory among Vietnam combat veterans. Similarly, this study investigated whether categorical group membership (PTSD or PTSD and mild TBI) could be predicted based on any of the nine between-domains measures. First, the nine between-domains measures were subjected to exploratory factor analysis (EFA) using the maximum likelihood extraction method with a varimax rotation to maximize the spread of variance and produce a more well defined set of factors (Spicer, 2005). The purpose of this EFA was to determine whether these nine measures could be further reduced into a smaller number of underlying factors. The EFA yielded three factors with eigenvalues greater than 1.0, accounting for 48.01% of the total variance (see Table A17). Factor one consisted of the dominant hand and non-dominant hand trials of *Finger Tapping Test*. Factor two consisted of the *Letter-Number Sequencing* subtest, *Trailmaking Test Part B*, *D-KEFS Letter Fluency*, *Block Design* subtest, and *Vocabulary* subtest. Factor three consisted of the *CVLT-II Learning Slope* and *Long Delay Free Recall* scores.

Next, a logistic regression analysis was performed where the three factors identified in the EFA were entered as the predictor variables and diagnostic group was entered as the dichotomous categorical dependent variable. The purpose of the logistic regression was to determine whether any of these factors derived from the factor analysis were able to accurately predict PTSD or PTSD and mild TBI group membership. As shown in Table A18, results of the logistic regression analysis revealed that none of the three factors emerged as a significant predictor of diagnostic group membership. Moreover, the regression model performed only minimally better than chance in that it was only able to correctly predict group membership in 52% percent of cases. In sum, these results indicate that the test performance of OEF/OIF combat veterans with PTSD and PTSD and mild TBI was not significantly different on the three factors derived from the nine between-domains measures such that it would allow for accurate prediction of diagnostic group membership.

Examining Psychological Functioning

A final goal of this study was to further examine and compare the psychological functioning of both diagnostic groups of OEF/OIF combat veterans through the use of both a self-report measure of depression, the *BDI-II*, as well as a self-report measure of anxiety, the *BAI*. First, two ANOVAs were conducted with diagnostic group entered as the independent variable and participants' *BDI-II* and *BAI* scores entered as the dependent measures. Results revealed that OEF/OIF combat veterans with uncomplicated PTSD did not differ significantly from those with PTSD and comorbid mild TBI on either the *BDI-II*, $F(1, 97) = .15$, $p = .70$, or the *BAI*, $F(1, 88) = .12$, $p = .73$, suggesting comparable psychological functioning. Although significant differences were not found between groups on these two measures of psychological functioning, it still is important to note that mean *BDI-II* and *BAI* scores for both groups fell in the moderate severity range based on the interpretation guidelines for each measure. Thus, both groups endorsed elevated levels of comorbid psychopathology and psychological dysfunction in addition to PTSD.

Chapter 5

Discussion

This study yielded three important findings. First, results indicated that OEF/OIF combat veterans with PTSD and comorbid mild TBI did not differ significantly from those with uncomplicated PTSD on objective tests of neuropsychological functioning. Second, neither group of OEF/OIF combat veterans demonstrated neuropsychological deficits across any of the measures examined. Third, despite a lack of demonstrated neuropsychological deficits, this study found that both groups of combat veterans reported elevated, though comparable, levels of comorbid anxiety and depression. Although nonsignificant findings typically are disappointing to the researcher, in this case the lack of significant performance deficits observed among both groups offers unique insight into the overall cognitive and psychological functioning of OEF/OIF combat veterans. Because far less research has been conducted with the OEF/OIF population relative to previous cohorts of combat veterans, this study offers neuropsychologists, psychologists, and other healthcare providers a novel understanding of the concerns experienced by this new generation of combat veterans. Below, each of the three main findings will be discussed within the context of this study's research questions followed by a discussion of the study's limitations. Finally, implications for future research and clinical practice with the OEF/OIF combat veteran population are presented.

Finding One: Nonsignificant Group Differences

One of the primary objectives of this study was to investigate whether the neuropsychological functioning of OEF/OIF combat veterans with PTSD and comorbid mild TBI significantly differed from those with uncomplicated PTSD. As such, perhaps the most salient finding of this study is that OEF/OIF combat veterans with PTSD and comorbid mild TBI did not significantly differ from those with uncomplicated PTSD on objective tests of neuropsychological functioning. More specifically, no significant performance differences between groups were detected on the between-domains measures, nor were these measures able to accurately predict diagnostic group membership. Further, with the exception of one possibly anomalous score (i.e., *WCST Perseverative Responses*), no significant performance differences between groups were detected on the within-domains measures of neuropsychological functioning as well.

The nonsignificant differences between groups were consistent with two previously discussed positions in the literature. First, this study offers additional support for the position that individuals with a mild TBI often will recover from the cognitive impairments associated with the injury over time (Belanger, et al., 2005; Frencham et al., 2005; Ruff, 2005). Findings from the current investigation suggest that if a TBI results in initial additional cognitive sequelae, it likely diminishes over time. Second, results of this study offer additional support for recent findings that suggested that self-reported mild TBI symptoms may not remain significant once PTSD symptom severity is controlled (Belanger et al., 2010; Hoge et al., 2008). This study expanded on these preliminary findings by investigating performance *across* multiple domains of neuropsychological functioning, as well as *within* the individual domains. Collectively, results suggest that post-acute mild TBI does not appear to produce any additive impairment in cognitive functioning among OEF/OIF combat veterans with PTSD beyond uncomplicated PTSD.

A final point worth mentioning is that the neuropsychological assessment data examined in this study were obtained from post-deployment combat veterans who were well past the acute stage of mild TBI. Therefore, while this study's results supports the conclusion that OEF/OIF combat veterans with PTSD and comorbid mild TBI do not significantly differ from those with PTSD at the post-acute stage in terms of cognitive functioning, this same finding may not replicate in a population of combat troops with acute mild TBI. While mild TBI symptoms typically diminish quickly over first few weeks for the majority of individuals, post-concussion symptoms frequently are present for a period after the injury was sustained (Belanger et al., 2005; Frencham et al., 2005; Ruff, 2005; Schretlen & Shapiro, 2003). In this case, it may be that those with PTSD and a mild TBI, especially those troops still in active combat zones, may demonstrate more neuropsychological impairment during this acute phase where more pronounced post-concussion symptoms are likely to be present. Unfortunately, given the retrospective design of this study, this issue was not able to be investigated further, but remains a rich area for future research.

Finding Two: Intact Neuropsychological Performance

Beyond examining group differences, a second objective of this study was to examine the neuropsychological performance for both groups to determine if any notable deficits emerged. The second key finding is that neither the uncomplicated PTSD group nor the PTSD and mild TBI group demonstrated significant performance impairments across the multiple instruments of neuropsychological functioning examined in this study. Two notable exceptions to this trend are that both groups performed approximately one full standard deviation below the mean and in the low average range on both the *Trail Making Test Part A* as well as the *CVLT-II Recognition* score, which is consistent with past reviews that reported that attention and memory are the two domains of neuropsychological functioning most commonly affected by PTSD (Horner & Hamner, 2002; Vasterling & Brailey, 2005). Beyond these two measures, both groups' performance on the remaining between-domains and within-domains measures was within the average range or better, a finding which is somewhat inconsistent with past studies (e.g., Gilbertson et al., 2001; Uddo et al., 1993).

The relatively intact test performance of both groups still was somewhat unexpected, especially considering that the assessment scores included in this study were gathered from a population of treatment-seeking OEF/OIF combat veterans. Thus, if these veterans' subjective cognitive symptoms were problematic enough to warrant them seeking neuropsychological evaluation services, it is somewhat surprising that more frequent and pronounced neuropsychological impairments were not found on objective testing. This finding raises the issue of how subjective cognitive complaints associated with PTSD may be inconsistent with the results of objective neuropsychological testing, and may instead be reflective of other contributing factors such as comorbid psychopathology (Carlozzi, Reese-Melancon, & Thomas, 2010; Roca & Freeman, 2001).

Finding Three: Elevated Comorbid Psychopathology

The third key finding of this study is that although no significant differences were detected between diagnostic groups on measures of psychological functioning, a further examination of OEF/OIF combat veterans' scores on these measures revealed that both groups self-reported elevated levels of comorbid psychopathology. More specifically, both the PTSD and comorbid mild TBI and the uncomplicated PTSD groups endorsed symptoms of comorbid depression as well as anxiety in the moderate severity range. Thus, it remains a reasonable hypothesis that the comorbid psychological concerns experienced by both groups of OEF/OIF combat veterans may be contributing to the subjective cognitive difficulties that served as the impetus for seeking assessment services.

Elevated comorbid psychopathology combined with the lack of neuropsychological deficits observed, suggests that factors other than mild TBI, such as comorbid mental health concerns, may also be important to consider when providing services to OEF/OIF combat veterans (Belanger, Uomoto, & Vanderploeg, 2009). Terrio and colleagues (2009) also suggested that residual TBI cognitive symptoms may be associated with comorbid behavioral health concerns among Army members who served in Iraq. For instance, Carlozzi and colleagues (2010) also found that self-reported problems with memory were more commonly associated with depression as opposed to actual objective memory impairment among patients with PTSD. Likewise, Chamelian and Feinstein (2006) found that mild to moderate TBI patients with subjective cognitive complaints performed worse than TBI patients without subjective complaints on objective neuropsychological testing. However, most of these differences between groups failed to remain significant once comorbid depression was controlled. Thus, the relative lack of observed impairments across tests among both groups of combat veterans in this study underscores the importance of considering comorbid psychological dysfunction as a potential cause underlying subjective cognitive complaints. Interestingly, although these findings highlight the importance of comorbid psychological concerns, it has been reported that OEF/OIF veterans may be more open to TBI diagnoses and more willing to attribute current complaints and symptoms to a TBI while being less accepting of mental health diagnoses (Belanger et al., 2009; Brenner et al., 2009).

The finding that OEF/OIF veterans with PTSD and comorbid mild TBI did not demonstrate pronounced neuropsychological impairments or significantly differ from those with uncomplicated PTSD, despite subjective complaints, also raises the issue of additional factors that may underlie subjective cognitive complaints beyond comorbid psychopathology.

Specifically, these findings also may relate to the issue of "diagnosis threat" or the hypothesis that negative expectations can actually influence performance on objective neuropsychological testing (Suhr & Gunstad, 2002). For instance, Mittenberg, DiGiulio, Perrin, and Bass (1992) found that subjects without a history of head injury who were asked to imagine having sustained a concussion reported symptoms that were nearly identical to actual post-concussion symptoms. They concluded that expectation appeared to share as much variance with post-concussion syndrome as the actual head injury. Similarly, Ferguson, Mittenberg, Barone, and Schneider (1999) found that athletes with mild head injuries largely overestimated post-concussion symptoms, which seemed to result from perceived symptom expectations. Likewise, the results of an experiment by Suhr and Gunstad (2002) indicated that participants with mild head injuries assigned to a diagnosis threat group performed significantly worse on certain cognitive tests relative to a neutral control group of participants with mild head injuries. A common theme emerging from these studies is that expectations associated with a mild TBI appear to have the potential to influence one's perception and subjective symptoms. Therefore, given the role of expectation on perceived post-concussion symptoms, early intervention efforts may include providing individuals who recently sustained a mild TBI with information regarding both the role of expectation in symptom persistence as well as accurate information about the course and symptoms associated with TBI (Ferguson et al., 1999).

Study Limitations

Despite the interesting findings of this study, several limitations were present that are important to consider. First, premorbid baseline information was unavailable. Therefore, while this study was able to determine whether either diagnostic group's current cognitive functioning was impaired, it was not possible to examine whether their current neuropsychological functioning represented a significant change from past levels of functioning. More specifically, performance across tests largely was in the average range for both groups; however, without objective baseline data being available, it was not possible to determine whether this average range performance represents a significant decrease from previous levels of cognitive functioning. This limitation is not unique to the current study and frequently is noted as a challenge when examining neuropsychological TBI outcomes among a civilian population as well (Dikmen, Machamer, & Temkin, 2009).

Another limitation of this study relates to the record review methodology, which limited analysis to the neuropsychological measures actually administered to each patient. Thus, while this study was able to comprehensively examine combat veterans' neuropsychological functioning using both between and within domains measures, it was not possible to examine information not already contained in each OEF/OIF combat veteran's record. One example that illustrates this limitation is how the construct of "diagnosis threat" seemed as if it could offer some insight into the unimpaired objective neuropsychological performance found among OEF/OIF combat veterans reporting subjective cognitive complaints in this study. Because no information regarding mild TBI symptom and recovery expectations was included in the records, it was not possible to further explore this hypothesis. Similarly, the neuropsychological data examined in this study focused almost exclusively on cognitive outcomes associated with mild TBI and did not include measures like the *Key Behaviors Change Inventory* (*KBCI*) that assess common neurobehavioral difficulties associated with mild TBI, such as interpersonal difficulties and impulsivity (Kolitz, Vanderploeg, & Curtiss, 2003). Finally, the sample was largely male and White. Thus, future research should investigate whether results replicate on a more diverse sample of combat veterans.

Future Directions and Practice Implications

As OEF/OIF combat troops return from duty, PTSD and mild TBI resulting from exposure to combat undoubtedly will affect and interfere with multiple important aspects of functioning and readjusting to civilian life including returning to work or pursuing further educational ambitions (Slone & Friedman, 2008). Despite the psychosocial implications of conditions such as PTSD and mild TBI, there exists a relative lack of empirical research with regard to providing treatment for comorbid conditions (Belanger et al., 2009). Moreover, the authors noted that healthcare providers often will be presented with the challenge of having to determine the appropriate sequence of treatment interventions for combat veterans with PTSD and mild TBI. As such, this issue of treatment sequencing remains important to consider from the standpoint of delivering effective psychological and neuropsychological interventions.

In considering treatment sequencing, Terrio and colleagues (2009) advocated for a "stepwise approach" (p. 21) that incorporated an educational component followed by addressing common behavioral sequelae associated with mild TBI (e.g., sleep difficulties, headaches, irritability), prior to addressing self-reported cognitive difficulties. Vanderploeg and colleagues (2009) also argued that PTSD is a stronger predictor of physical, cognitive, and emotional symptoms than mild TBI. The authors further asserted that PTSD treatment should be prioritized in order to effectively address residual symptom complaints associated with mild TBI and to increase overall treatment outcomes. In many ways, results of the present study are consistent with this position that it may be more efficacious to prioritize addressing common behavioral sequelae of mild TBI and treatment of PTSD and other mental health symptoms first considering the lack of impairment found among OEF/OIF combat veterans with PTSD and mild TBI as well as the nonsignificant performance differences compared to those with uncomplicated PTSD.

Finally, returning to this issue of "diagnosis threat" previously discussed, it is important to consider that negative expectations can actually impact subjective complaints (Mittenberg et al., 1992; Suhr & Gunstad, 2002). Thus, addressing comorbid psychopathology as well as expectation also remains critical to consider and incorporate into developing effective intervention and treatments for OEF/OIF combat veterans with mild TBI (Brenner, 2009).

Conclusion

The purpose of this study was to investigate the neuropsychological functioning of OEF/OIF combat veterans with PTSD and to determine if the neuropsychological functioning of those with PTSD and a comorbid mild TBI significantly differed from those with uncomplicated PTSD. Results of this study suggested three main findings. First, the cognitive functioning of OEF/OIF combat veterans with PTSD and mild TBI did not differ significantly from those combat veterans with uncomplicated PTSD on any of the between-domains or the within-domains measures of neuropsychological functioning examined in this study. This suggests that if initial cognitive symptoms associated with mild TBI existed post-injury, they largely resolved over time and were not pronounced at the time of evaluation. Second, neither diagnostic group of OEF/OIF combat veterans demonstrated notable performance deficits across the battery of neuropsychological tests examined in this study. Third, both diagnostic groups reported depressive and anxiety symptoms in the moderate severity range, which suggests that both groups experience elevated levels of comorbid psychological dysfunction. The relative lack of objective neuropsychological performance deficits combined with elevated levels of psychopathology suggest that comorbid mental health conditions, not mild TBI, may underlie the subjective cognitive complaints. Moreover, findings from previous studies highlight how expectation may play a role in subjective neuropsychological complaints, though this study was not able to investigate this issue directly. Finally, given that mild TBI did not appear to add any substantial cognitive sequelae above PTSD, results of this study support emerging research suggesting that treatment aimed at first addressing PTSD and associated mental health conditions may prove advantageous in treating combat veterans with comorbid mild TBI.

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Appendix A

Tables

Table A1

Participant Demographic Characteristics

Demographic Variable	PTSD (n = 59)	PTSD/TBI (n = 66)
Gender		
Male	58 (98%)	65 (98%)
Female	1 (2%)	1 (2%)
Race		
White	53 (90%)	61 (92%)
African American	4 (7%)	1 (2%)
Hispanic/Latino/a	2 (3%)	3 (4%)
Other	0 (0%)	1 (2%)
Handedness		
Right handed	50 (85%)	60 (91%)
Left handed	9 (15%)	5 (8%)
Ambidextrous	0 (0%)	1 (1%)
Relationship Status		
Single	9 (15%)	12 (18%)
In a relationship	8 (14%)	12 (18%)
Married	32 (54%)	32 (49%)
Separated	3 (5%)	2 (3%)
Divorced	7 (12%)	8 (12%)
Military Branch		
Army	28 (47%)	41 (62%)
Marines	11 (19%)	13 (20%)
Navy	3 (5%)	1 (1%)
Air Force	1 (2%)	0 (0%)
National Guard	16 (27%)	11 (17%)
Deployment Location		
Afghanistan	2 (3%)	8 (12%)
Iraq	52 (88%)	54 (82%)
Both Afghanistan/Iraq	4 (7%)	4 (6%)
Other	1 (2%)	0 (0%)

Table A2

Additional Demographic Characteristics

Demographic Variable	PTSD *M* (*SD*) (*SE*)	PTSD/TBI *M* (*SD*) (*SE*)
Age	33.5 (10.7) (1.4)	27.5 (4.8) (0.6)
Education completed (years)	13.0 (1.6) (0.2)	13.0 (1.6) (0.2)
Deployment length (months)	13.7 (7.5) (1.0)	13.6 (7.6) (1.0)
Time since injury (months)	--------------------	37.5 (18.5) (2.5)
Self-reported PTSD symptoms (*Mississippi Scale*)	104.0 (16.3) (2.9)	100.2 (19.4) (3.3)

Table A3

Between-Domains (Primary) Measures

Measure	PTSD *M* (*SD*) (*SE*)	PTSD/TBI *M* (*SD*) (*SE*)
Attention		
Letter-Number Sequencing	99.0 (11.1) (1.5)	99.0 (14.7) (1.8)
Learning and Memory		
CVLT-Learning Slope	100.5 (15.8) (2.5)	100.4 (13.9) (2.0)
CVLT-Long Delayed Free Recall	93.0 (19.9) (3.1)	92.6 (16.0) (2.3)
Executive Functioning		
Trail Making Test Part B	91.4 (17.2) (2.3)	92.0 (15.2) (1.9)
Language		
Letter Fluency	95.6 (17.7) (2.6)	95.1 (15.8) (2.2)
Visuospatial Functioning		
Block Design	107.6 (14.2) (1.9)	106.8 (12.0) (1.5)
Motor Functioning		
Finger Tapping (dominant)	93.0 (17.2) (2.3)	92.1 (16.5) (2.2)
Finger Tapping (non-dominant)	96.5 (17.1) (2.3)	94.4 (16.1) (2.1)
Intellectual Functioning		
Vocabulary	100.6 (13.3) (1.7)	101.1 (12.8) (1.6)

Note. The between-domains test scores are from the following measures: *Letter-Number Sequencing*: *Wechsler Memory Scale-Third Edition* (*WMS-III*); *Learning Slope and Long Delayed Free Recall*: *California Verbal Learning Test-Second Edition* (*CVLT-II*); *Trail Making Test Part B*: *Halstead-Reitan Neuropsychological Test Battery*; *Letter Fluency*: *Delis-Kaplan Executive Function System* (*D-KEFS*); *Block Design*: *Wechsler Abbreviated Scale of Intelligence* (*WASI*); *Finger Tapping Test*: *Halstead-Reitan Neuropsychological Test Battery*; *Vocabulary*: *Wechsler Abbreviated Scale of Intelligence* (*WASI*). All scores are presented as *standard scores*.

Table A4

Within-Domains Measures-Attention

Measure	PTSD *M* (*SD*) (*SE*)	PTSD/TBI *M* (*SD*) (*SE*)
Focus-Execute		
Ruff 2&7-Total Speed	92.0 (14.8) (3.0)	90.1 (15.6) (2.8)
Ruff 2&7-Total Accuracy	94.4 (15.5) (3.2)	96.5 (10.3) (1.8)
Shift		
WCST Non-Perseverative Errors	102.1 (14.1) (2.0)	104.7 (11.7) (1.6)
Sustain		
Trail Making Test Part A	84.7 (19.4) (2.6)	85.0 (15.1) (1.9)
Encode		
Digit Span	95.8 (13.1) (1.9)	97.1 (12.9) (1.8)

Note. The within-domains attention test scores are from the following measures: *Ruff 2 & 7-Total Speed* and *Ruff 2 & 7-Total Accuracy*: *Ruff 2 & 7 Selective Attention Test*; *WCST Non-Perseverative Errors*: *Wisconsin Card Sorting Test*; *Trail Making Test Part A*: *Halstead-Reitan Neuropsychological Test Battery*; *Digit Span*: *Wechsler Memory Scale-Third Edition* (*WMS-III*). All scores are presented as *standard scores*.

Table A5

Within-Domains Measures-Verbal Memory

CVLT-II Score	PTSD *M* (*SD*) (*SE*)	PTSD/TBI *M* (*SD*) (*SE*)
Trials 1-5 Correct	96.5 (16.1) (2.5)	99.0 (15.9) (2.2)
Short Delay Free Recall	95.5 (17.3) (2.7)	94.9 (13.6) (1.9)
Long Delay Free Recall	93.0 (19.9) (3.1)	92.6 (16.0) (2.3)
Proactive Interference	101.1 (14.0) (2.2)	97.7 (13.2) (1.9)
Retroactive Interference	102.1 (11.6) (1.8)	97.7 (10.6) (1.5)
Recognition Hits	83.3 (26.5) (4.1)	81.6 (22.1) (3.1)
Recognition False Positives	99.0 (11.0) (1.7)	99.9 (12.8) (1.8)
Total Intrusions	97.0 (20.5) (3.2)	95.6 (20.5) (2.9)

Note. CVLT-II = *California Verbal Learning Test-Second Edition*. All scores are presented as *standard scores*. In order to maintain consistency in score direction where a lower standard score represents poorer test performance, the *Recognition False Positives* and *Total Intrusion* scores were reverse scored on this measure.

Table A6

Within-Domains Measures-Visual Memory

RCFT Score	PTSD *M* (*SD*) (*SE*)	PTSD/TBI *M* (*SD*) (*SE*)
Immediate Recall	98.3 (20.4) (3.7)	92.9 (20.8) (3.4)
Delay Recall	93.3 (23.0) (4.1)	91.0 (19.6) (3.2)
Recognition	96.5 (14.6) (2.6)	97.2 (19.4) (3.2)

Note. RCFT = *Rey Complex Figure Test*. All scores are presented as *standard scores*.

Table A7

Within-Domains Measures-Executive Functioning

WCST Score	PTSD *M* (*SD*) (*SE*)	PTSD/TBI *M* (*SD*) (*SE*)
Total Errors	104.3 (15.3) (2.1)	106.9 (14.7) (2.0)
Perseverative Responses	111.0 (21.8) (3.0)	119.0 (20.5) (2.8)
Perseverative Errors	109.3 (21.2) (2.9)	116.7 (19.5) (2.6)
Non-Perseverative Errors	102.1 (14.1) (2.0)	104.7 (11.7) (1.6)
Conceptual Level Responses	104.7 (14.8) (2.1)	107.0 (12.2) (1.6)
Categories Completed	5.6 (1.1) (0.2)	5.8 (0.9) (0.1)
Failures to Maintain Set	1.1 (1.3) (0.2)	0.7 (1.1) (0.1)
Trials Administered	92.5 (20.9) (2.9)	88.7 (18.9) (2.6)

Note. WCST = *Wisconsin Card Sorting Test*. The *Total Errors*, *Perseverative Responses*, *Perseverative Errors*, *Non-Perseverative Errors*, and *Conceptual Level Responses* scores are presented as *standard scores*. The *Categories Completed*, *Failures to Maintain Set*, and *Trials Administered* scores are presented as raw scores (*Categories Completed* potential range = 0-6; *Failures to Maintain* possible range = 0-24; *Trials Administered* possible range = 0-128).

Table A8

Within-Domains Measures-Language

D-KEFS Score	PTSD *M* (*SD*) (*SE*)	PTSD/TBI *M* (*SD*) (*SE*)
Letter Fluency	95.6 (17.7) (2.6)	95.1 (15.8) (2.2)
Category Fluency	102.5 (20.6) (3.0)	103.7 (18.3) (2.5)

Note. *D-KEFS = Delis-Kaplan Executive Function System*. All scores are presented as *standard scores*.

Table A9

Psychological Functioning

Measure	PTSD *M* (*SD*) (*SE*)	PTSD/TBI *M* (*SD*) (*SE*)
BDI-II	20.5 (12.4) (1.8)	21.5 (11.9) (1.7)
BAI	21.1 (11.9) (1.9)	21.9 (10.9) (1.6)

Note. BDI-II = *Beck Depression Inventory – Second Edition*; BAI = *Beck Anxiety Inventory*. All scores are presented as raw scores (possible range = 0-63).

Table A10

Between-Domains Measures Intercorrelations

Score	LN	LS	LDR	TMT	LF	BD	FTD	FTN	VO
LN	1	-.02	.08	.25	.25	.24	.18	.06	.26
LS	.22	1	.53**	-.06	-.12	.12	-.03	-.11	.22
LDR	.31*	.35*	1	.36*	.34*	.28	-.01	.03	.44**
TMT	.13	.06	.05	1	.27	.11	.50**	.47**	.17
LF	.28	-.03	.08	.23	1	.35*	.04	.04	.35*
BD	.34**	.06	-.03	.25	.26	1	.22	.07	.51**
FTD	.10	-.16	.02	-.02	.41**	-.05	1	.78**	.24
FTN	.18	-.05	.26	.02	.35*	-.16	.63**	1	.15
VO	.17	.15	.16	.29*	.41**	.47**	.03	-.17	1

Note. LN = *Letter-Number Sequencing*; LS = *CVLT-II Learning Slope*; LDR = *CVLT-II Long Delay Free Recall*; TMT = *Trail Making Test Part B*; LF = *D-KEFS Letter Fluency*; BD = *Block Design*; FTD = *Finger Tapping Test* (dominant hand); FTN = *Finger Tapping Test* (non-dominant hand); VO = *Vocabulary*. The intercorrelations for the PTSD group are presented above the diagonal and the intercorrelations for the PTSD/TBI group are presented below the diagonal.

* $p < .05$; **$p < .001$

Table A11

Within-Domains Measures-Attention Intercorrelations

Score	2/7S	2/7A	TMT	WCSTN	DS
2/7S	1	.04	.21	.36	.25
2/7A	.14	1	-.73**	.44	-.24
TMT	.31	.13	1	-.23	.13
WCSTN	.38	-.10	.19	1	-.16
DS	.19	.20	.13	.12	1

Note. 2/7S = *Ruff 2 & 7 Selection Attention Test-Total Speed*; 2/7A = *Ruff 2 & 7 Selection Attention Test-Total Accuracy*; TMT = *Trail Making Test Part A*; WCSTN = *Wisconsin Card Sorting Test-Non-Perseverative Errors*; DS = *Digit Span*. The intercorrelations for the PTSD group are presented above the diagonal and the intercorrelations for the PTSD/TBI group are presented below the diagonal.

* $p < .05$; ** $p < .001$

Table A12

Within-Domains Measures-Verbal Memory Intercorrelations

Score	T15	SDR	LDR	PI	RI	RH	FP	TI
T15	1	.77**	.78**	-.19	-.07	.66**	.42**	.01
SDR	.74**	1	.82**	-.31*	.41**	.76**	.32*	.02
LDR	.73**	.77**	1	-.11	.11	.86**	.37*	.14
PI	-.27	-.19	-.16	1	-.37*	-.15	.15	.46**
RI	-.26	.28*	.03	-.16	1	.14	-.07	-.30
RH	.64**	.55**	.64**	-.07	-.09	1	.20	.04
FP	.26	.27	.27	-.17	-.00	-.11	1	.36*
TI	.16	.34*	.23	-.12	.22	.18	.39**	1

Note. All scores are from the *California Verbal Learning Test-Second Edition* (*CVLT-II*). T15 = *Trials 1-5 Correct*; SDR = *Short Delay Free Recall*; LDR = *Long Delay Free Recall*; PI = *Proactive Interference*; RI = *Retroactive Interference*; RH = L*ong Delay Yes/No Recognition Hits*; FP = *Long Delay Yes/No Recognition False Positives*; TI = *Total Intrusions*. The intercorrelations for the PTSD group are presented above the diagonal and the intercorrelations for the PTSD/TBI group are presented below the diagonal.

* $p < .05$; ** $p < .001$

Table A13

Within-Domains Measures-Visual Memory Intercorrelations

Score	IR	DR	REC
IR	1	.93**	.35
DR	.91**	1	.38*
REC	.26	.32	1

Note. All scores are from the *Rey Complex Figure Test* (*RCFT*). IR = *Immediate Recall*; DR = *Delayed Recall*; REC = *Recognition*. The intercorrelations for the PTSD group are presented above the diagonal and the intercorrelations for the PTSD/TBI group are presented below the diagonal.

* $p < .05$; ** $p < .001$

Table A14

Within-Domains Measures-Executive Functioning Intercorrelations

Score	TE	PR	PE	NE	CR	CC	FM	TA
TE	1	.92**	.92**	.94**	.98**	.71**	-.51**	-.85**
PR	.76**	1	.99**	.76**	.91**	.51**	-.43*	-.72**
PE	.78**	.98**	1	.77**	.91**	.51**	-.44**	-.72**
NE	.85**	.65**	.68**	1	.93**	.81**	-.58**	-.87**
CR	.89**	.83**	.86**	.91**	1	.69**	-.44**	-.80**
CC	.46**	.43**	.45**	.54**	.55**	1	-.43**	-.70**
FM	-.26	-.18	-.25	-.40**	-.28*	-.43**	1	.76**
TA	-.78**	-.63**	-.67**	-.84**	-.78**	-.54**	.62**	1

Note. All scores are from the *Wisconsin Card Sorting Test* (*WCST*). TE = *Total Errors*; PR = *Perseverative Responses*; PE = *Perseverative Errors*; NE = *Non-Perseverative Responses*; CR = *Conceptual Level Responses*; CC = *Categories Completed*; FM = *Failures to Maintain Set*; TA = *Trials Administered*. The intercorrelations for the PTSD group are presented above the diagonal and the intercorrelations for the PTSD/TBI group are presented below the diagonal.

* $p < .05$; ** $p < .001$

Table A15

Within-Domains Measures-Language Intercorrelations

Score	LF	CF
LF	1	.78**
CF	.62**	1

Note. All scores are from the *Delis-Kaplan Executive Function System* (*D-KEFS*). LF = *Letter Fluency*; CF = *Category Fluency*. The intercorrelations for the PTSD group are presented above the diagonal and the intercorrelations for the PTSD/TBI group are presented below the diagonal.

* $p < .05$; ** $p < .001$

Table A16

Psychological Functioning Intercorrelations

Score	BDI-II	BAI
BDI-II	1	.60**
BAI	.73**	1

Note. *BDI-II = Beck Depression Inventory – Second Edition*; *BAI = Beck Anxiety Inventory*. The intercorrelations for the PTSD group are presented above the diagonal and the intercorrelations for the PTSD/TBI group are presented below the diagonal.

* *p* < .05; ***p* < .001

Table A17

Summary of Between-Domains Measures Factor Loadings

Measure	Factor Loading 1	2	3
Finger Tapping Test (non-dominant)	**.96**	-.01	.02
Finger Tapping Test (dominant)	**.74**	.20	-.13
Vocabulary	-.01	**.71**	.17
Block Design	-.04	**.68**	.01
D-KEFS Letter Fluency	.20	**.50**	.10
Letter-Number Sequencing	.13	**.35**	.13
Trailmaking Test Part B	.27	**.30**	.12
CVLT-II Long Delay Free Recall	.12	.20	**.97**
CVLT-II Learning Slope	-.09	.09	**.45**

Note. Boldface indicates highest factor loadings.

Table A18

Summary of Variables in the Logistic Regression Equation

	B	SE	Wald	df	Sig
Factor 1	.002	.015	.020	1	.888
Factor 2	.013	.026	.243	1	.622
Factor 3	.000	.017	.002	1	.965
Constant	-1.350	2.866	.222	1	.638

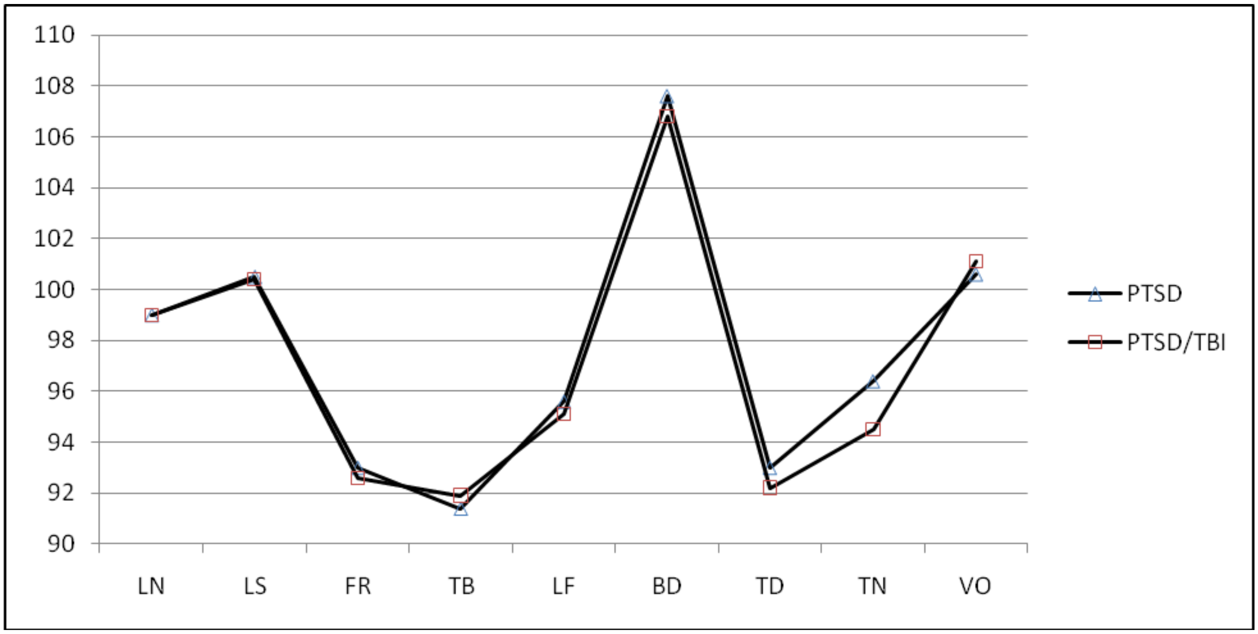
Note. Factor 1: *Finger Tapping Test* (dominant hand and non-dominant hand trials); Factor 2: *Letter-Number Sequencing* subtest, *Trailmaking Test Part B*, *D-KEFS Letter Fluency*, *Block Design* subtest, and *Vocabulary* subtest; Factor 3: *CVLT-II Learning Slope* and *Long Delay Free Recall*.

Appendix B

Figures

Figure B1

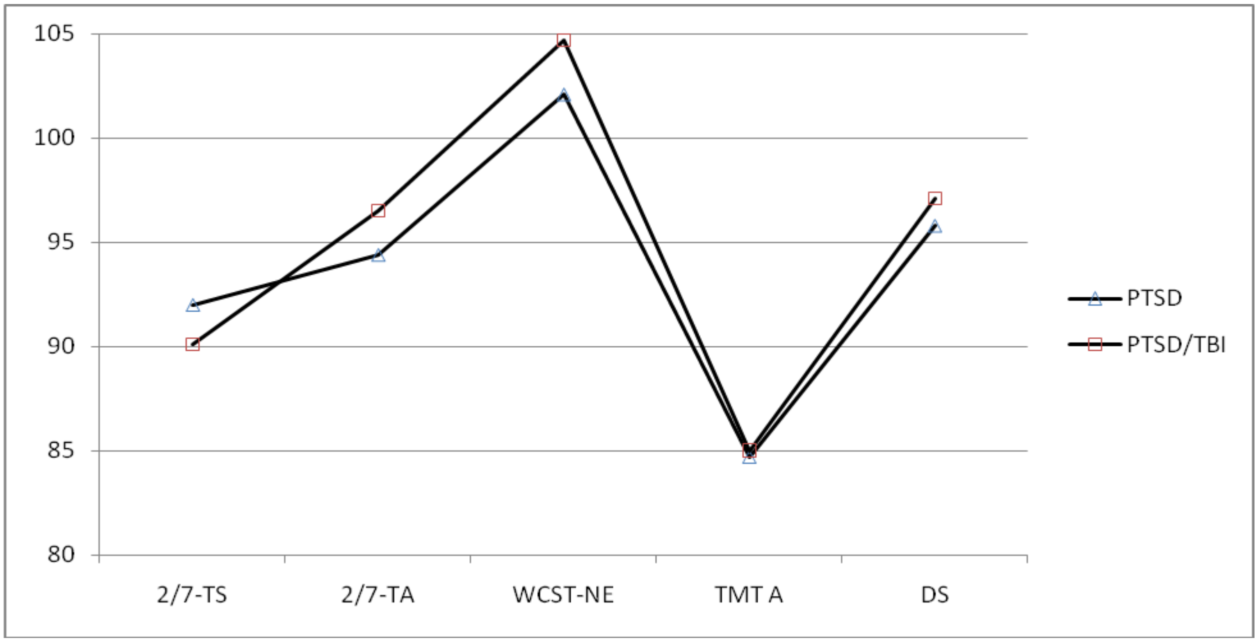
Between-Domains Neuropsychological Profiles



Note. LN = *Letter-Number Sequencing*; LS = *CVLT-II Learning Slope*; FR = *CVLT-II Long Delay Free Recall*; TB = *Trail Making Test Part B*; LF = *D-KEFS Letter Fluency*; BD = *Block Design*; TD = *Finger Tapping Test* (dominant hand); TN = *Finger Tapping Test* (non-dominant hand); VO = *Vocabulary*.

Figure B2

Within-Domains Neuropsychological Profiles-Attention



Note. 2/7-TS = *Ruff 2 & 7 Selection Attention Test-Total Speed*; 2/7-TA = *Ruff 2 & 7 Selection Attention Test-Total Accuracy*; WCST-NE = *Wisconsin Card Sorting Test-Non-Perseverative Errors*; TMT A = *Trail Making Test Part A*; DS = *Digit Span*.

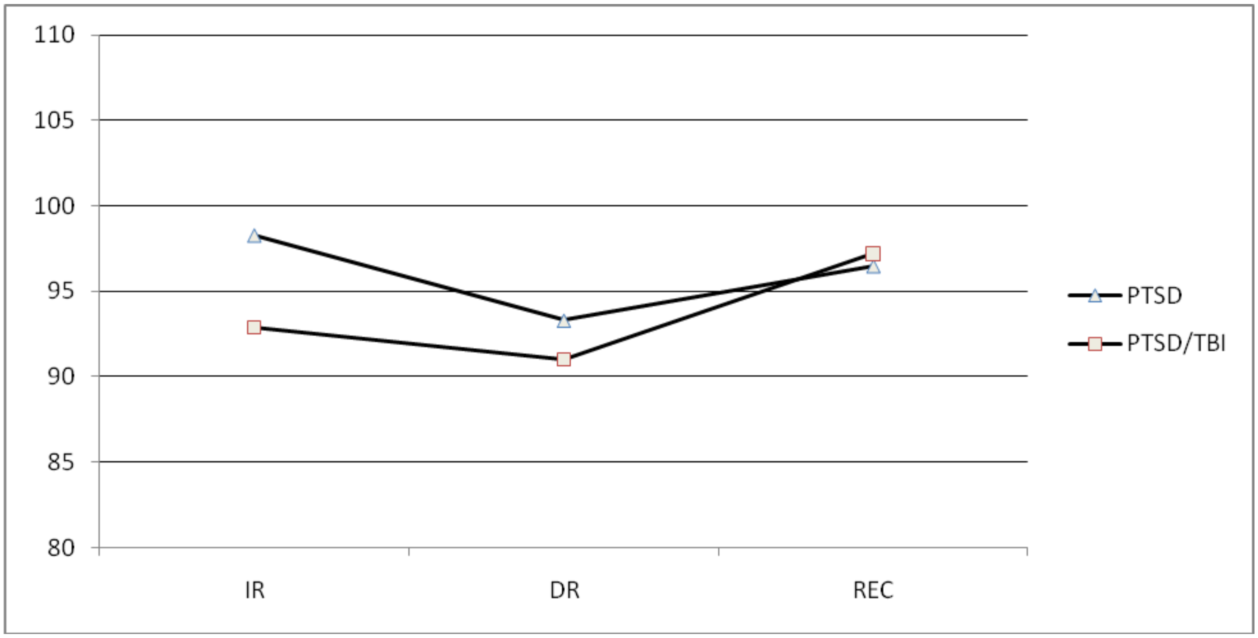
Figure B3

Within-Domains Neuropsychological Profiles-Verbal Memory

Note. All scores are from the *California Verbal Learning Test-Second Edition* (*CVLT-II*). T1-5 = *Trials 1-5 Correct*; SDR = *Short Delay Free Recall*; LDR = *Long Delay Free Recall*; PI = *Proactive Interference*; RI = *Retroactive Interference*; RH = *Long Delay Yes/No Recognition Hits*; FP = *Long Delay Yes/No Recognition False Positives*; TI = *Total Intrusions*.

Figure B4

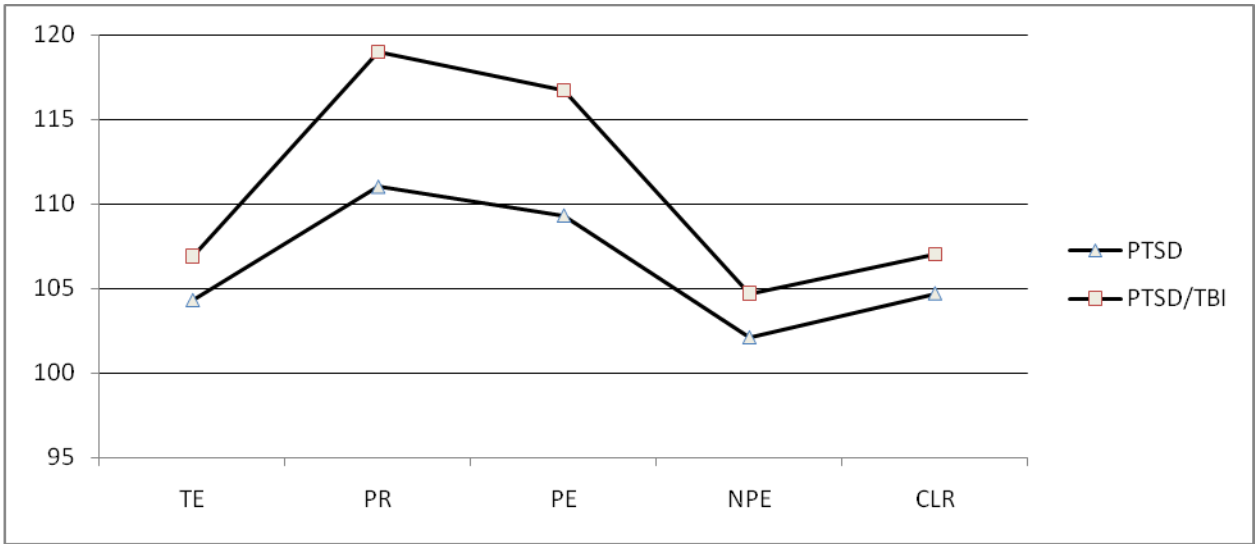
Within-Domains Neuropsychological Profiles-Visual Memory



Note. All scores are from the *Rey Complex Figure Test* (*RCFT*). IR = *Immediate Recall*; DR = *Delayed Recall*; REC = *Recognition*.

Figure B5

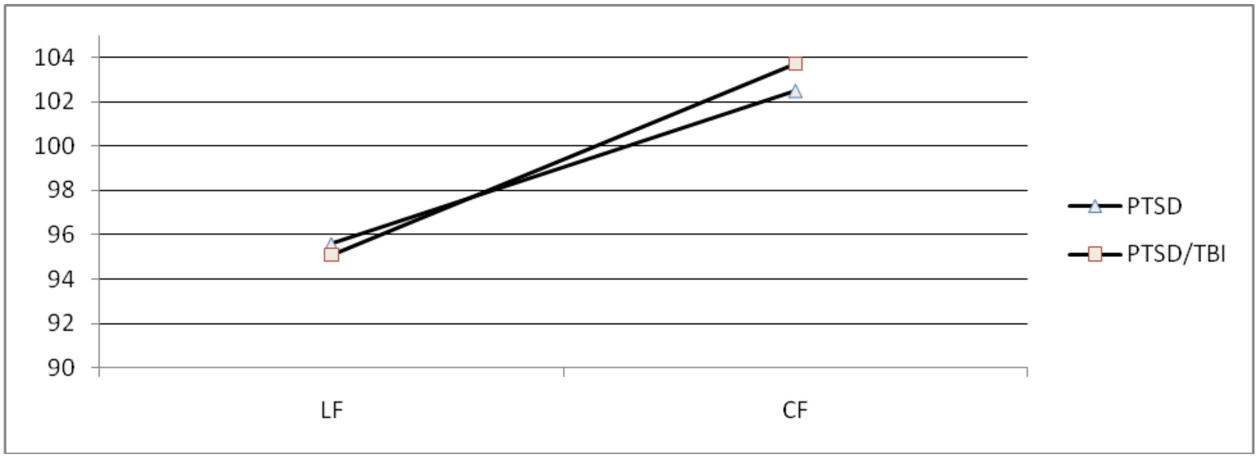
Within-Domains Neuropsychological Profiles-Executive Functioning



Note. All scores are from the *Wisconsin Card Sorting Test* (*WCST*). TE = *Total Errors*; PR = *Perseverative Responses*; PE = *Perseverative Errors*; NPE = *Non-Perseverative Responses*; CLR = *Conceptual Level Responses*.

Figure B6

Within-Domains Neuropsychological Profiles-Language



Note. All scores are from the *Delis-Kaplan Executive Function System* (*D-KEFS*). LF = *Letter Fluency*; CF = *Category Fluency*.